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REPORT NO T13-92

CHANGES IN SOLDIER NUTRITIONAL STATUS & IMMUNE FUNCTION DURING THE RANGER TRAINING COURSE

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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Technical Report No. T13-92

CHANGES IN SOLDIER NUTRITIONAL STATUS & IMMUNE FUNCTION DURING THE RANGER TRAINING COURSE

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September 1992

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a REPORT SECURITY CLASSIFICATION: Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: U.S. Army Research Institute of Environmental Medicine; 6b OFFICE SYMBOL (If applicable): SGRD-UE-OP	7a NAME OF MONITORING ORGANIZATION: U.S. Army Medical Research & Development Command
6c ADDRESS (City, State, and ZIP Code): Natick, MA 01760-5007	7b ADDRESS (City, State, and ZIP Code): Fort Detrick, Frederick, MD 21702-5012
8a NAME OF FUNDING/SPONSORING ORGANIZATION; 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
0603002A	3M263002 D819	AI	DA320522

11 TITLE (Include Security Classification)
Changes in Soldier Nutritional Status & Immune Function during the Ranger Training Course (U)

12 PERSONAL AUTHOR(S) Moore, Robert J.; Friedl, Karl E.; Kramer, Tim R.; Martinez-Lopez, Lester E.; Hoyt, Reed W.; Tulley, Richard E.; DeLany, James P.; Askew, E. Wayne; Vogel, James A.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM June 91 TO Jan 92	1992 September 10	162

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	nutrition, energy expenditure, energy intake, weight loss, immune function, physical performance, medical problems, cellulitis, body composition, vitamins, clinical chemistry

19 ABSTRACT (Continue on reverse if necessary and identify by block number) Prompted by several infectious disease epidemics and the perception that weight loss was excessive, the US Army Ranger Training Brigade requested an assessment of the effect of restricted rations on nutritional status, physical performance, and immune function during summer Ranger training. A comprehensive physiological evaluation of 55 volunteers who completed all 4 phases of the 8-1/2 wk course was made at the beginning and end of the course, with abbreviated measurements made at the end of each 2 wk phase. The study revealed that Ranger students have a decreased protection against infection, with decreased T-lymphocyte function. There was no evidence of a vitamin, mineral, or protein deficiency despite reduced rations, and extensive clinical chemistry profiles were remarkably normal, indicating that this is an uncomplicated energy deficiency (average energy expenditure & intake: 4010 & 2800 kcal/day, respectively). Weight loss was high (15.6% of weight) but recovery to original fitness levels occured by 6 months after the end of training. It is concluded that as little as 300-400 kcal/day increase in intakes may attenuate decrements in physical performance and immune function. A follow-on study of the effects of an intervention using the LLRP ration is proposed.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION: Unclassified
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ACKNOWLEDGMENTS

We are greatly indebted to the soldiers who volunteered to participate in this study over and above the requirements of Ranger training.

We are grateful to SSG Glenn Thomas and Ms. Elaine Christensen for their expert organizational and technical work which made this study a success. Other members of the field study team included Mr. Lou Marchitelli, Mr. Peter Frykman, SPC Michael Johnson, Mr. Robert Petrin, SGT Kong Ang, MAJ Barry Fairbrother, SGT Marlon Shelby, Mr. Jeff Tate, SPC Sonya Moore-Shelby, Ms. Kate O'Brien, and SPC Sherryl Kubel. MAJ O'Dell, C, Nursing, Cutler Army Community Hospital, Fort Devens generously augmented our field phlebotomy team. Data analysis support was provided by Ms. Bonnie Beam, Mr. John Finn, and Ms. Brooke Cheema. We thank LTC Robert Burr, M.D., for conducting physical examinations for nutritional deficiencies at the end of Ranger training. Dr. Claire C. Gordon, from the Science & Advanced Technology Directorate, US Army Natick Research, Development & Engineering Center, very kindly advised us on the expedient anthropometric measurements used in this study and provided direct support of the study by Mr. Robert Petrin, research anthropologist.

This study required more than 10,000 biological specimen analyses. The technical staff of the Clinical Chemistry Laboratory at Pennington Biomedical Research Center had the largest workload and still produced a high quality and timely analysis. Mr. Lou Marchitelli, at USARIEM, singlehandedly performed all of the endocrine assays for this study and managed a large portion of the database. We received excellent microbiology and hematology support from CPT James M. Camp (Martin Army Community Hospital), CPT Daniel H. Atchley (Eglin Hospital), and MAJ Hugh M. Gelston, Jr. and 1LT Carmen D. Hernandez (Wm Beaumont Army Medical Ctr).

This line of investigation was initiated because COL Thomas I. Clements (TRADOC Command Surgeon) requested an EPICON meeting at the Ranger school and encouraged USARIEM involvement. This study was only made possible because COL John J. Maher III (Commander, Ranger Training Brigade) recognized the usefulness of the Army's medical research services in improving his organization. Several members of the Ranger Training school directly contributed to the success of this study, notably LTC Clyde M. Newman, CPT Rennie M. Cory and SSG Charles R. Judd, in the first phase, and MAJ Pat Walsh and SSG Troy S. Glassman, in the last phase; they were Rangers who "made it happen." Other unknown members of the school cadre ensured samples and data were collected at appropriate times and forwarded to our research team.

The results of this study were briefed to the Ranger Training Brigade (COL Maher, 9 Jan 92), Medical Research & Development Command (MG Travis, 21 Feb 92), The Surgeon General of the Army (LTG Ledford, 27 Mar 92), and the DOD Food and Nutrition Research and Engineering Board (13 May 92). The results were also presented to and reviewed in depth by the National Academy of Sciences' Committee on Military Nutrition Research, including several special consultants (Per Kristian Opstad, M.D., Norwegian Defence Research Establishment; John M. Kinney, M.D., The Rockefeller University; William R. Beisel, M.D., Johns Hopkins School of Hygiene and Public Health; Walter Mertz, M.D., U.S. Department of Agriculture, Beltsville; Thomas R. Ziegler, M.D., Harvard Medical School). The conclusions and recommendations of the Committee are included at Appendix III.

Finally, the support and encouragement of USARIEM Commander COL Gerald P. Krueger and USAMRDC Research Area III Director COL David D. Schnakenberg was instrumental in accomplishing this study.

SUMMARY

During Ranger training soldiers lose more body weight and suffer relatively higher rates of infection compared to soldiers undergoing less rigorous field training. The relationships between restricted food intakes, sleep deprivation, mental and physical stress with body weight loss and susceptibility to infection of Ranger students has not been studied. Recent episodes of pneumococcal pneumonia among Ranger students resulted in a request from the Commander of the Ranger Training Brigade for a scientific investigation which would be a first step in addressing the relationship between the nutritional status, body weight loss, and immunocompetence of soldiers undergoing Ranger training.

Soldiers from a single Ranger training class (conducted from July through September 1991) were studied; 190 students began the study, and 55 soldiers from the original cohort completed all phases of the 62-day course. A comprehensive battery of physiological, physical performance, and immunological measurements were made at the beginning and end of the course, with more limited sampling conducted at the end of each two-week phase. The four training phases were: Phase I, temperate forest (Ft. Benning/Camp Darby, Georgia), Phase II, mountains (Camp Merrill, Georgia), Phase III, jungle (Camp Rudder, Eglin AFB, Florida), and Phase IV, desert (Ft. Bliss, Texas). On 35 of the 62 days of the course, students were provided a single meal (equivalent to one MRE/day; 1300 kcal). Samples and measurements were taken to determine: 1) changes in body weight and the composition of body weight loss, muscular strength, and muscular endurance, 2) energy expenditure, 3) nutritional status (biochemical assessment of protein/calorie, vitamin, and mineral status), 4) <u>in vitro</u> and <u>in vivo</u> cellular immune function, and 5) the incidence of infection, injuries, and other medical problems.

<u>Attrition</u>. Of the original sample of 190 students, end-of-course measurements were made on 55 students (29%) but only 33 students (17%) met all course requirements and graduated in a single pass. Additional members of the study group were recycled into subsequent classes, resulting in 90 students (47%) eventually graduating to earn the Ranger tab. From the original sample, 40 students (21%) were recycled or dropped from the course for medical reasons.

<u>Changes in body composition & physical performance</u>. Students lost an average of 15.6% (range: 9-23%) of their body weight (11.8 kg) and body fat declined

from 14.6% (5.7-26.1%) to 5.8% (4.4-11.9%); thus, fat loss represented 61% of the total weight loss and this loss reduced estimated available fat stores by more than 90%. Fat-free mass losses averaged 4.6±2.6 kg (6.9±3.6% of initial values). Since most of this represents loss of muscle tissue and muscle mass represents only about half of the fat-free mass, it can be estimated that most students lost greater than 10% of their muscle tissue. There was no significant loss of bone mineral. Isometric grip strength and grip holding endurance (60% of maximum grip strength) were not significantly changed during the course, but a maximum lift strength declined from 77 kg to 59 kg during the course. Soldiers losing the most muscle mass suffered the largest decrements in lift strength.

Energy expenditure & water requirements. Average daily energy expenditure was 4010 kcal/day. Energy expenditure was variable during the course, ranging from 3150 kcal/day during the early desert phase to over 6000 kcal/day during the mountain phase. The daily energy expenditures were met by approximately 2800 kcal/day from food and 1200 kcal/day from body energy stores; thus, there was a net energy deficit of 31% produced by periodically restricted rations. The largest relative energy deficits were observed during the mountain (37%) and jungle phases (33%), while a more modest relative energy deficit was seen during the desert phase (15%). The lower deficit during the desert phase largely reflected higher food intakes during the pre-FTX portion of the phase. Estimates of water turnover for each of the four phases were 8.5, 6.1, 6.8, and 5.0 liters/day.

Nutritional assessment. Biochemical markers of protein/energy metabolism, and of selected vitamins and minerals were determined in fasting blood samples collected initially and at the end of each training phase. The results indicate that no overt vitamin or mineral deficiencies were present at sampling times, regardless of whether students were using vitamin/mineral supplements. This suggests that diet and body stores provided sufficient vitamins and minerals to meet metabolic requirements, even during periods of reduced nutrient intakes. Most indicators of metabolism (e.g. glucose, serum protein, albumin, β-hydroxybutyrate, fatty acids, urea nitrogen) remained within normal limits. There was a transient decline in glucose and rise in urea nitrogen during the course, indicative of an increase in protein catabolism. Nutrient intakes, averaged for the entire 62-day period, met the MRDA for most nutrients, except for energy. Large and consistent declines in hormonal markers such as insulin-like growth factor-1, triiodothyronine, and testosterone support the conclusion that the major nutritional insult of the Ranger course is sustained energy

deficit, although the data cannot rule out the occurrence of periodic metabolic deficiencies of specific amino acids, vitamins or minerals during the periods of most severe food restriction.

Cellular immune function. Immune function was reduced by the end of the first phase, with the greatest and most uniform impairment at the end of the mountain phase (week 4), followed by a partial recovery at the end of the desert phase (week 8-1/2). This recovery coincided with the period during which the smallest energy deficit existed. Reduced T- and B-lymphocyte proliferation in response to mitogen exposure suggests that resistence to infectious agents was reduced to the greatest extent during the mountain and jungle phases; reduced plasma concentrations and cellular production of interleukin-6 after the jungle phase suggests an impairment in the ability of the immune system to recruit assistance in controlling inflammation and infection.

Medical problems. Infection rates increased from 8% of the class during the mountain phase to 25% of the class during the jungle and desert phases. The infections were primarily soft-tissue infections (cellulitis), most often affecting the knees. Aggressive treatment with antibiotics by medical personnel was a likely reason that medical attrition from this class was not higher. The number of students identified as carriers of Group A beta-hemolytic Streptococcus remained low throughout the course, but Streptococcus pneumoniae carriage rates increased to 12% of the class by the jungle phase.

The weight loss was substantial in this group of soldiers. Although a large portion of the energy deficit was compensated for by utilizing fat stores for energy, a significant amount of fat-free mass was also lost. The consequence of this loss of muscle mass was manifested in a 23% decrease in lifting strength. Most soldiers were able to maintain blood-borne markers of nutritional status within normal limits throughout the course. A significant finding was the dramatic suppression in cellular immune function which occurred in the course, and the observation that the suppression coincided with the periods of highest infection rates. There was a partial recovery in cellular immune function at the end of the course, which coincided with a period of refeeding and a reduction in the magnitude of the energy deficit. The results of this study suggest that the high levels of energy expenditure coupled with restricted food supply during Ranger training increase the risk of susceptibility to infection.

PREFACE

This report emphasizes the nutritional stress of Ranger training. However, Ranger training is a multistressor environment also encompassing high energy expenditure, sleep deprivation, anxiety, heat or cold depending on the time of year (ours was a summer Ranger class), and other stressors such as blistered feet and infection. A stressful environment is a critical aspect of the course, where soldiers are evaluated for their ability to set aside their basic needs in order to lead their patrol and accomplish the mission. The school has control over two key stressors, food and sleep deprivation, and these are probably the most important aspects of the suppressed immunocompetence and loss of weight which we report here. Anxiety about success in the course is not likely to play a large role because there is little room for it on top of sleeplessness and hunger and because soldiers know that as long as they are still in the course they are still succeeding; in any case, this is not greater in magnitude than would be experienced in other Army courses. Manifestations of many of the other stressors (e.g. cold sensitivity, upper limits of energy expenditure) are integrally linked to food deprivation. The stress responses measured in this study reflect primarily sleep and energy deficits. The influence of sleep deprivation was not evaluated in this study, making it difficult to separate the individual and additive effects of these stressors on immune function. We believe that relatively small improvements in sleep time and/or energy deficit may attenuate the immune function decrement we observed.

The results of the classic Minnesota starvation-refeeding study (1) provide the closest comparison to this study because of the high weight losses resulting from low energy intakes. However, there are some significant differences between our study and the Minnesota study. The Minnesota study was designed to replicate starvation conditions and examine refeeding strategies for individuals experiencing famine and starvation at the end of WWII. That study was also performed with healthy young male volunteers on restricted rations. However, ration restriction was continuous and was the only deliberate stressor in otherwise sedentary men. In contrast, the soldiers in our study had brief refeeding opportunities at the beginning of each 2-week training phase and they remained very physically active even during periods of caloric restriction. A second difference is that volunteers in the Minnesota study were pushed to a greater weight loss (individual goal ≅ 25% of body weight) than our Ranger student volunteers (average weight loss = 15.6% of body weight). There are appropriate physiological responses, such as the sacrifice of fat mass over lean and a

reduction in resting metabolic rate, which protect and optimize physiological function in these conditions. However, with a continued energy deficit carried to its extreme, there is no adaptation which prevents death when carried to its extreme; the soldiers in our study were in an early part of this continuum. They used nearly all of their available fat supplies but, unlike the Minnesota Study, were only just beginning to catabolize portions of their lean mass. Thus, Ranger students are physiologically challenged with energy deprivation but they have not been pushed into the category of emaciation which would describe the semi-starved volunteers in the Minnesota Study.[1]

This study addressed specific questions posed to us by the Ranger Training Brigade Commander. Because of the special environment of the Ranger training program, the extremely strenuous training, and the importance of this course to military careers of the volunteers who compete to attend, we could not design the study to control all experimental variables that would normally be controlled in a scientific study on exercise, food and sleep deprivation, and weight loss. With this study we have been able to describe the very interesting physiology of Ranger training. As a consequence of our findings, some aspects of this training have already been changed and thus our description represents an earlier baseline which is in some respects already obsolete as a description of Ranger training. This study is highly relevant in that it may have produced a better and safer training course by quantifying nutritional stress limits which should not be duplicated or exceeded. In addition, a well planned applied study can usually lead to new understandings of basic mechanisms. This study demonstrated the remarkable ability of the body to accommodate a severe caloric deficit, with clinical chemistries remaining within normal limits even as the lower end limits of body fat were achieved; this degree of weight loss has been usually studied only in sick patients with other complicating characteristics.

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[1]Even so, the Commander of the Ranger Training Brigade determined that an average weight loss of 15% of body weight is too much, relative to the goals of Ranger training, and he adopted changes in the ration schedule within 24 hours of the initial outbrief of results of this study.

INTRODUCTION

The US Army Ranger Training Course is a demanding 62-day training program designed to teach and evaluate individual leadership and small unit tactics under physically and mentally demanding conditions. The course subjects trainees to multiple stressors including restricted food availability, sleep deprivation, and periods of sustained physical exertion, as 7-10 day periods of simulated combat patrols, in diverse climatic and terrain environments.

A Ranger class typically experiences an overall attrition rate of 50-60%. Approximately one-half of the attrition (25-30% of the original class) has been attributed to illness or injury (2). Additionally, many Ranger trainees receive medical treatment for other injuries, illnesses, and infections but are subsequently removed from the course for non-medical reasons, or complete the course in spite of the illness. Ranger training poses a significant medical threat to the trainee because of the low food intake, sleep deprivation, high energy expenditures, and limited opportunities for personal hygiene.

The ration provisions, sleep regimes, and training tasks in the Ranger training schedules are designed to create a high-stress environment which permits realistic evaluations of trainee ability without subjecting them to unnecessary health risks. In early 1991, a Ranger class experienced a significant outbreak of pneumococcal pneumonia (3). Fourteen cases (6% of the class) were diagnosed as clinical pneumonia and over 33% of the trainees were identified as Streptococcus pneumoniae carriers, with 91% of the carriers reporting cough or rhinorrhea. These observations indicated that Ranger trainees exhibited a higher S. pneumoniae carriage rate than the general population, yet it was unclear if the higher rate resulted from greater environmental exposure, or reflected an impaired ability to resist chronic or acute exposure to infectious agents. This pneumonia outbreak raised concerns that the multiple stressors associated with Ranger student training, specifically the reduced food intake and accompanying body weight losses, might be contributing to an unacceptably high susceptibility to illness or injury.

Since the inception of the Ranger training program during World War II, there has never been a systematic study of the impact of the program on Ranger health or susceptibility to disease. There have been studies conducted which have documented some of the physiological consequences of the course on trainees (4,5). A survey of

the Ranger course in 1976 (4) indicated that trainees lost an average of 15 pounds (9.4% of body weight) over the length of the course, with some soldiers losing as much as 17% of body weight. Most of the weight loss (57%) was body fat, but fat-free mass (5%) and water (38%) were also lost. These findings correspond with anecdotal reports from Ranger course graduates of body weight losses between 20 and 40 pounds. However, a recent study (5) reported that Ranger trainees only lost 8.5 pounds (5% of body weight) during the course, and that body fat content did not change.

Previous studies with Ranger trainees showed that soldiers consumed approximately 4000-4400 kcal per day when provided hot, prepared meals in a mess-type facility (4,6). However, a menu analysis of the 1989 Ranger feeding plan showed that soldiers were provided only 2400 kcal/day during the first 6 days of a summer Ranger training course (LTC Madeline S. Rose, unpublished results). During the 50 days of field training when trainees conduct combat patrols, the students are given rations which provide an average of less than 1500 kcal/day. Daily energy expenditure was about 4000 kcal (range 3200-5200 kcal/day)(4,6). If calorie intakes are estimated at 1400 kcal per day during FTX patrol phases (50 days) and 5000 kcal per day (18 days) during garrison training, a weight loss of approximately 30 pounds can be predicted.

The impact of the amount of food restriction and accompanying weight loss in the Ranger course on physical performance or physiologic function cannot be predicted from the available information. Feeding studies conducted with soldiers during field training exercises have shown that self-selected food intakes of 2000-3000 kcal daily produce weight losses of 5-10% of body weight (7-9), and are not accompanied by significant decrements in physical or mental performance. These data indicate that mild to moderate weight losses pose a minimal risk to the soldier, however, these studies have only been conducted for relatively short durations (less than 30 days) and have not included additional stressors such as sustained sleep deprivation, heavy physical work, etc.

Weights losses of less than 10% of body weight which occur in fewer than 10 days do not appear to be associated with performance decrements, as long as soldiers receive sufficient water and energy (approximately 1500 kcal per day) to prevent dehydration, hypoglycemia, and ketosis (10,11). Although field studies have shown that intakes of some minerals and vitamins are below the Military

Recommended Dietary Allowances (12), biochemical indicators of nutrient status have not detected any functional consequences of the reduced nutrient intakes (7-9, 13). Studies of the Norwegian Rangers have shown that during intense, 5-day field exercises, blood levels of stress-induced catabolic hormones (testosterone, estradiol, cortisol) can only be partly returned toward normal levels by increased calorie intakes (14-16). The physiological and nutritional consequences of prolonged calorie deprivation coupled with the high energy expenditures of the Ranger Training Course are not known, and it is not possible to predict whether an increase in calorie or specific nutrient intakes would reduce the large weight loss associated with the course.

While we know that protein/calorie malnutrition and single nutrient deficiencies impair in vivo and in vitro markers of immunocompetence (17-19) and can increase the incidence of nosocomial infections in certain populations (20-21), no comprehensive data are available which describe these changes in soldiers undergoing Ranger training. Thus, it is not possible to determine if the reduced food intake and accompanying weight loss is of sufficient severity to increase the susceptibility of the Ranger trainee to infectious disease, and if so, what would constitute an appropriate nutritional or non-nutritional intervention to correct the condition.

At the invitation of the Ranger School Commander (Appendix I), the present study was conducted to provide a longitudinal description of the nutritional and physiological impact of the Ranger course on the trainees. Blood and physiological measurements were collected to: 1) assess nutritional status by the measurement of specific blood-borne biochemical indicators of nutritional status, 2) examine changes in body composition and muscular strength and endurance, and 3) assess in vitro and in vivo immune function.

METHODS

RANGER TRAINING COURSE DESCRIPTION

The Ranger training course (22) is a 62-day training program which exposes soldiers to four different tactical and climatic environments: 1) Phase I: temperate forest, conducted at Camp Rogers and Camp Darby at Fort Benning, Georgia, 2) Phase II: forested mountains, conducted at Camp Merrill, Georgia, 3) Phase III: coastal swamp/jungle, conducted at Camp Rudder, Eglin Air Force Base, Florida, and 4) Phase IV: desert, conducted at Fort Bliss, Texas. Each phase is about 14 days in duration, and includes an introductory training period (3-7 days duration) of classroom and field instruction of techniques and skills unique to the particular environment, followed by intensive 7-10 day simulated combat patrols away from the installation. A detailed course decription is in Appendix II.

Prior to beginning the course each prospective Ranger trainee must complete the Ranger Assessment Phase (RAP), which is conducted on the four days immediately before Phase I. On RAP day 1, trainees take a physical fitness test (as described in AR 350-15)(23), meeting the 80% standard for 18 year olds, and with the addition of pullups) and the Combat Water Survival Test; on RAP day 2, trainees complete a morning 5-mile run (8:00 minute per mile pace) in shorts and running shoes and an afternoon 8-mile road march with weapon and 35 pound rucksack load (initial 15:30 minute per mile pace gradually reduced to 20:00 minute per mile pace); on RAP day 3, trainees complete day and night land navigation courses; on RAP day 4, subjects retake land navigation (if not passed on day 3) and take a series of military skills tests (passing 32 of 36 tasks as described in Appendix II)(24).

Students are given several opportunities to repeat and pass the course requirements before being dropped from the course. Soldiers with an academic or medical problem can be recycled within a phase if it is determined by the training camp commander, or by the Physician's Assistant, that the respective problem can be rehabilitated in time for the soldier to continue with the next class, 30 days later. More serious problems lead to a drop from the course and a soldier who returns later must repeat the whole course.

TEST SUBJECTS

This study was reviewed and approved by the USARIEM Human Use Review Committee, the Human Use Review Office at USAMRDC, and was conducted in accordance with USAMRDC Reg No. 70-25 and AR 70-25 (25). All participants in the study were volunteers, and were recruited from class 91-11. All students were briefed on the purpose and aims of the study on or prior to RAP day 1. After being briefed, volunteers were required to read and sign a Volunteer Agreement Affidavit, certifying that the procedures of the study had been explained to them and acknowledging that they could leave the study at any time without any adverse consequences.

The original study population consisted of 190 male volunteers out of 261 members of class 91-11. Fifty-five soldiers finished the course and were available for measurements, however, only 33 soldiers successfully completed all course requirements and graduated at the end of the course. Attrition during the RAP was not different between the test volunteer subset (35.8%) and the entire class (33.3%). Descriptive data for the initial test volunteer population and the population of trainees who completed the course are presented in Table 1.

EXPERIMENTAL DESIGN

The experiment was designed to collect longitudinal data on trainees at each phase of the course. An experiment time line is presented in Table 2, which includes the location, weather data, ration provision schedule, and subject measurement dates. Daily caloric intake estimated from this ration schedule is illustrated in Figure 1. No other food was permitted in this course and violation of this rule was enforced with immediate dismissal for an adverse Special Observation Report (SOR). Baseline data was collected on all trainees prior to beginning the course, and then at the completion of each training phase. Specific methods will be discussed in detail in subsequent sections, but the following section provides an overview of the data collection procedures.

Specimens and data were collected five times during the course to assess nutritional status, body composition, muscular strength and endurance, and immune function: baseline and at the end of each of the four training phases described earlier. Although all four general areas of interest were evaluated, not every measurement was made at each data collection point. The specific measurements made at each

Table 1. Baseline descriptive data of all soldiers starting and soldiers completing (Finishers) Ranger training. There were no statistical differences between groups.

	All Soldiers	Finishers
Item[1]	n=190	n=55
Age, years	24.3±3.8 (18-41)	23.6±2.8 (18-31)
Weight, kg	76.6±9.2 (46.4-106.6)	75.9±8.9 (63.2-99.8)
Height, cm[2]	176.2±6.9 (144.7-191.6)	176.6±6.2 (165.4-191.6)
Body fat, %[3]	14.8±4.4 (5.4-28.0)	14.6±4.2 (5.7-26.1)
Ethnicity, number		
Non-hispanic white	149 (78%)	44 (80%)
Black	19 (10%)	4 (7%)
Hispanic	13 (7%)	5 (9%)
Asian	4	1
Native American	1	1
Other	4	0
Military Rank		
E2-E4	80 (42%)	26 (47%)
E5-E7	40 (21%)	9 (16%)
O1-O2	62 (33%)	20 (36%)
O3-O5	8 (4%)	0
Tobacco users, number		
Cigarettes	35 (18%)	6 (11%)
Smokeless	67 (35%)	20 (36%)
Coffee users, number	54 (28%)	16 (29%)

[1]Mean±standard deviation (range), or count (percent of total sample).
[2]Crotch height, arm span, and sitting height were also not significantly different between finishers and all soldiers; however, crotch height of Ranger students averaged 86.3±4.6 cm, putting them at the 70th percentile for Army men (26), suggesting that long-leggedness may be a discriminating trait in these volunteers.
[3]Body fat determined by dual energy x-ray absorptiometry (DEXA).

Table 2. Calendar, Temperature (T), Relative Humidity (RH), Precipitation (Precip), and Ration Schedule for Ranger Class 11-91

Date		Phase	T (max/min) (°F)	RH (max/min) (%)	Precip (inches)	Ration Schedule		
						Breakfast	Lunch	Dinner
July	26	I	84/70	78/59	.07	MRE	MRE	MRE
	27		86/59	81/57	.02	A	MRE	MRE
	28		85/70	81/55	.04	A	MRE	MRE
	29		89/71	81/50		A	MRE	A
	30		87/70	81/57		A	MRE	MRE
	31		86/69	79/53		A	MRE	MRE
August	1		85/70	73/53	.05	A	MRE	A
	2		87/68	78/48		A	MRE	MRE
	3		91/70	78/78	Trace	A		
	4		91/71	79/50		MRE		
	5		94/71	79/37		MRE		
	6		93/71	78/44		S		
	7		90/70	78/47		A		
	8		92/70	78/42		MRE		
	9		92/71	76/44	.14	MRE		
	10		88/72	73/49	.28	MRE	A	A
	11	II						A
	12		70/56	na	.28	A		B
	13		71/57	na	.27	A		A
	14		75/63	na	.46	A		B
	15		85/54	na		B		A
	16		78/60	na		A		A
	17		81/58	na		A		A
	18		82/60	na	.20	A		A
	19		85/68	na	.37	A		
	20		90/67	na		MRE		
	21		80/60	na	.70	MRE		
	22		82/60	na		MRE		
	23		84/64	na		[illegible]		
	24		86/63	na	.70	[illegible]		
	25		84/60	na	.90	MRE		
	26		86/61	na	.02	MRE		
	27					MRE	A	A
	28	III	89/76	97/56		No meals served		
	29		90/75	96/55	.25	A	BOX	A

Table 2. (continued)

Date		Phase	T (max/min) (°F)	RH (max/min) (%)	Precip (inches)	Ration Schedule Breakfast	Lunch	Dinner
	30		85/74	76/71	.42	A		MRE
	31		88/72	97/67	Trace	MRE	MRE	
Sept	1		90/75	94/54		MRE	MRE	
	2		92/74	97/47	.12	A		
	3		88/73	97/57	.06	MRE		
	4		86/73	90/59		MRE		
	5		86/73	94/70	.14	MRE		
	6		89/75	97/53		MRE		
	7		91/74	94/47	Trace	MRE		
	8		88/73	93/61		A		
	9		90/74	87/33		MRE		
	10		89/69	83/51		MRE		
	11		89/71	90/51		MRE		
	12		93/75	87/51		A	BOX	A
	13	IV					BOX	
	14		83/54	na		A	MRE	B
	15		80/45	na		A	MRE	B
	16		88/45	na		A	MRE	MRE
	17		92/52	na		A	MRE	B
	18		92/49	na		A	MRE	B
	19		79/47	na		MRE		
	20		83/44	na		MRE		
	21		83/50	na		MRE		
	22		79/58	na		MRE		
	23		77/51	na		MRE		
	24		73/61	na		MRE		
	25		77/47	na		MRE		
	26		78/42	na		MRE	MRE	A

notes: "S" denotes a survival meal comprised of a live rabbit or chicken and some vegetables shared between Ranger buddies; "A" rations are hot meals prepared in a food service facility; "B" rations are hot meals prepared from nonperishable items; Meal, Ready-to-Eat (MRE) rations are individual meals that can be eaten hot or cold and are intended for use during operations that preclude organized food service facilities; Box lunches (BOX) are individual meals usually composed of a sandwich, potato chips, fruit and a cold drink; for intake estimation purposes, an extra A ration has been added between each phase (10 Aug, 27 Aug, 12 Sep) when trainees were released on break for several hours and were permitted food ad libitum; na = data not available.

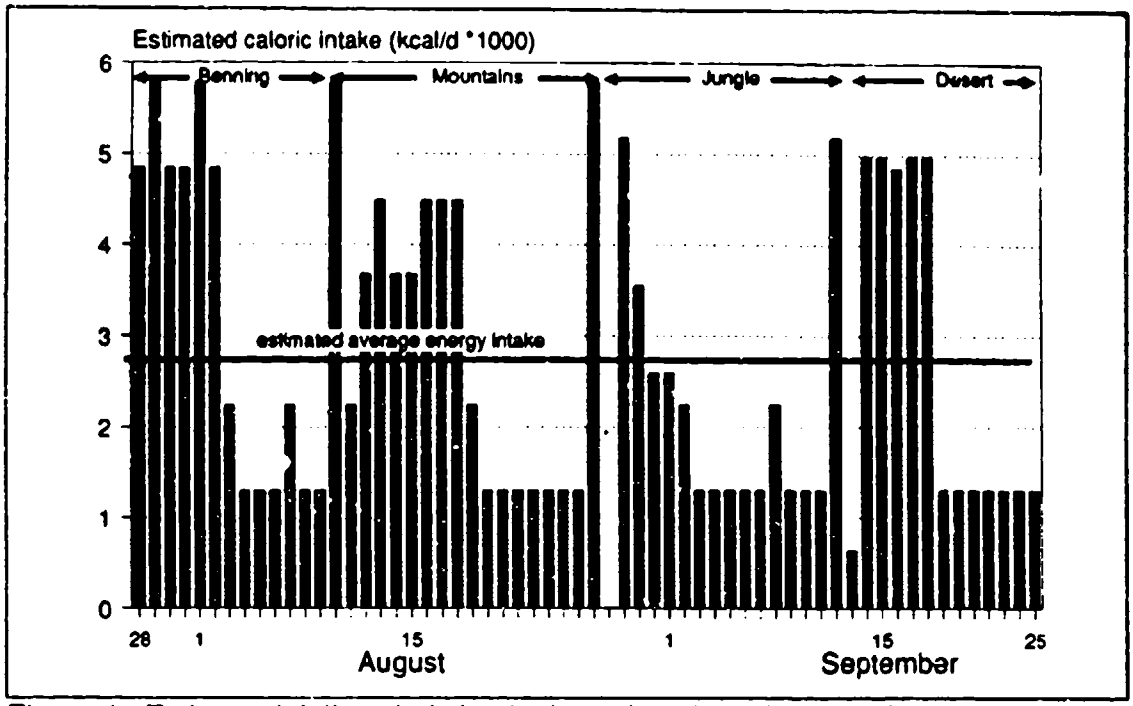


Figure 1. Estimated daily caloric intake based on the schedule of provided rations.

collection point are listed in Table 3. Measurements were made on subjects between 0430-0900 hours (except as noted below for baseline measurements). Volunteers reported (as units) to the data collection area within 4 hours of returning from all-night missions. In all cases, measurements were made on volunteers before they consumed any meals following their return from the field.

IDENTIFICATION AND QUANTIFICATION OF ATTRITION

All causes for soldier withdrawal from the Ranger training course were identified and grouped into four primary categories: medical, academic failure, voluntary withdrawal, and administrative removal. For medical withdrawals, a diagnosis was obtained from the medical records. At the end of each phase (starting with phase II), the medical treatment provided to students was obtained by reviewing all medical records initiated by the Physician's Assistant during the training phase. Additionally, subjective observations on the general condition of the soldiers were made at the end of each phase while each soldier was completely disrobed. Non-medical reasons for withdrawal from training were obtained from the Ranger training cadre.

Table 3. Data Measurements Made at Each Period

Measurement	Training Phase				
	BL	Benning	Mountain	Jungle	Desert
Body weight	x	x	x	x	x
Fasting blood sample (nutritional assessment)	x	x	x	x	x
Fasting blood sample (cell-mediated immunity)	x	x	x	x	x
Skin delayed hypersensitivity test	x			x	x
Throat and nasopharyngeal cultures	x	x	x	x	x
Circumference and skinfold measurements	x	x	x	x	x
DEXA measurements	x			x	x
Maximal grip strength	x				x
Grip strength endurance	x	x	x	x	x
Maximal incremental lift	x			x	x
Energy expenditure		x	x	x	x

Note: shorthand in this report includes baseline (BL), Benning (I), Mountain (II), Jungle/swamp (III), and Desert (IV).

Reasons for academic withdrawal included failing a majority of graded patrols, receiving an unsatisfactory peer rating from the other 11 squad members, receiving an excessive number of negative spot reports (e.g. sleeping on guard, losing equipment, etc.), or receiving a negative Special Observation Report for a more serious rules violation (e.g. eating unauthorized food). We reclassified a few cases of academic withdrawals as medical attrition when there was an underlying medical condition which caused the soldier to fail a critical patrol (e.g. patrol leader shot in the eye with a blank round during assault on an objective, or a soldier evacuated from the field for high fever related to cellulitis infection, before he could be graded for another patrol).

PHYSICAL TESTS

Body composition

Body weight, body composition, and anthropometric measurements were made at baseline and at the end of each training phase. Time constraints did not permit all measurements to be made at each of the five data collection times (summarized in Table 3).

Unless specifically noted, all measurements pertaining to body composition were made before subjects were permitted to eat on the data collection days. Nude weights were obtained using an electronic scale (SECA Model 708, SECA Instrument Co., Columbia, MD). A single set of linear anthropometric measurements was collected prior to beginning the study which included standing height (in stocking feet), sitting height, firm crotch height, and arm span (measured against a corner wall).

Six circumference measurements were made using a flexible steel tape over bare skin by an experienced anthropologist and a spotter (26). The six circumference measurements made were: flexed bicep, neck, shoulder, abdomen at the navel, hips, and thigh. Skinfolds were measured at four sites (biceps, triceps, suprailiac, and subscapula) as described by Durnin and Womersley (27). Skinfolds were measured three times and the measurements averaged.

Bone mass and soft tissue composition were measured using dual energy x-ray absorptiometry (DPX-Plus, Lunar Corp., Madison, WI), using methods described by Mazess et al. (28). Absorptiometry measurements were made at the beginning of the

study and at the end of Phases III and IV. Subjects were measured using a 10-minute "fast scan" mode, and measurements made on each subject at the ends of Phases III and IV were made on the same instrument the subject was originally measured on at the initiation of the study. Precision of the measurements for percent body fat is better than ±0.5% body fat units and for bone mineral content, ±0.040 kg (29).

Handgrip strength

Maximal isometric handgrip force was measured at the beginning of the study and at the end of phase IV using a customized ergometer which included a BLH electronic load cell transducer connected to a data acquisition system (30). The grip-dominant hand was tested in 3-4 trials, alternating between test subjects to encourage competition and permit muscular recovery between replicate trials. The grip device was adjusted to fit each individual before each trial.

Volunteers were instructed to keep their elbow in contact with the table and to position their shoulder over the elbow, keeping the elbow joint at approximately 90°. If the elbow was lifted from the table the trial was not used. Because the grip device was not anchored to the table, the test only measured the force provided by the fingers and thumb of the hand attempting to come together. Force was plotted in real time on a screen display in front of the subjects and subjects were verbally encouraged to produce their best effort. Peak force values were recorded and the highest two values from three trials were averaged. Only values which were within 10% of each other were used, and an additional trial was conducted in order to verify the highest value, in cases where adequate agreement between measurements was not achieved in three trials.

Handgrip endurance

Handgrip force endurance was measured by determining the holding time at 60±2.5% of maximal handgrip force (31). A screen display of the target force gave subjects two horizontal lines at 57.5% and 62.5% of maximal handgrip force and produced a real-time plot of a subjects holding performance. The volunteers were instructed to maintain a force within these limits, and when their grip force fell below 57.5% of the maximum for over 2 seconds, the test was terminated and the time in seconds recorded.

Five handgrip endurance measurements were made for each soldier (initial and at end of each training phase) using 60% of the maximum handgrip strength achieved at the baseline measurement period. A single handgrip endurance measurement was made using the maximum handgrip measurement taken at the end of Phase IV.

Maximal dynamic lift

Maximal lift capacity was measured before the course began, and at the end of Phases III and IV using instrumentation and methods described previously (31). For this procedure, weights are added to a carriage, to which handles are attached, and the carriage slides upward on a vertical track. The subject began by lifting 18 kg, followed by the addition of weight in each subsequent trial in increments of 18 kg until difficulty was encountered. Additional weight was added in increments of 9 kg until a maximum lift ability was achieved. A successful lift was defined as one in which the subject was able to raise the weighted carriage to shoulder height in one clean motion.

MEASUREMENT OF ENERGY EXPENDITURE & WATER TURNOVER

The experimental design for the energy balance and water turnover portion of the study is shown in Table 4. A limited supply of $H_2{}^{18}O$ resulted in energy expenditure measurements using the doubly labeled water (DLW) method being made on only 43 days of the 63-day experiment, and the number of DLW subjects was limited to six per phase. After attrition, the final number of DLW subjects for phases I through IV was 5,5,6,5, respectively. The mean age (23 yr), height (178 cm) and physical characteristics of the DLW subjects were similar to the overall group characteristics. Changes in baseline isotopic enrichment was simultaneously monitored in cohort groups of Ranger students who did not receive $^2H_2{}^{18}O$. During the three periods between DLW measurements, total daily energy expenditure (TDEE) was estimated as [(total intake balance energy expenditure - total DLW energy expenditure)/20 days].

The DLW ($^2H_2{}^{18}O$) method of measuring TDEE (32) is based on the assumption that after an initial oral dose of stable $^2H_2{}^{18}O$, deuterium (^2H) is eliminated from the body as water, whereas ^{18}O leaves as both water and exhaled carbon dioxide (CO_2). The rate of CO_2 production ($\dot{V}CO_2$) can be calculated from the difference in elimination rates of the two isotopes. Energy expenditure is calculated from $\dot{V}CO_2$ using a metabolic fuel quotient and conventional indirect calorimetric relationships. Total body

Table 4. Experimental design for energy balance and water turnover studies.

Phase	RAP & Benning				Mountain					Jungle			Desert		
Day of course	2	3	6	10	19	20	22	26	32	38	39	49	56	57	63
DLW dose		✓				✓					✓			✓	
Saliva sample	✓				✓					✓			✓		
Urine sample	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

water, isotopic elimination rates, carbon dioxide production, and metabolic fuel respiratory quotient were calculated using standard methods (33) as previously described (34,35). This method has been validated in soldiers in the field (34,35).

Water influx and efflux were measured by administering the stable, non-radioactive isotope ^2H_2O and following the decline over time in the isotopic enrichment of body water (36,37). The isotopic enrichment of body water declines due to the elimination of labeled water via excretion and evaporation, and the influx of unlabeled water from dietary, metabolic, and atmospheric sources. The ^2H_2O elimination method of measuring preformed dietary water intake has been validated in humans (38), and the tritiated water elimination method has been validated in animals (37). We estimated apparent total water turnover from deuterium distribution space and elimination rates. About 10% of the apparent total water turnover can be attributed to metabolic water production and respiratory and cutaneous water influx.

Intake balance energy expenditure was estimated using standard methods (39). Food intake was estimated from the overall ration schedule for the course (Table 2). A total of 56 of the 107 meals (52% of the meals; 41% of the total kcal consumed) consisted of one Meal-Ready-to-Eat ration (1300 kcal/meal). A total of 41 of the 107 meals were A rations. Energy intake for A ration meals was estimated at 2246 kcal (two times the calculated energy content of a standard serving). Of the remaining meals, 7 were B rations (estimated calorie content = 1433 kcal/meal) and three were box lunches (estimated calorie content = 690 kcal/meal). The change in body energy stores (ΔES) was estimated using the body composition measurements obtained by DEXA, using the equation: $(\Delta ES) = (\text{fat mass} \times 9.5 \text{ kcal/g}) + (\text{FFM} \times 0.27 \times 4.4 \text{ kcal/g})$, where FFM is fat free mass corrected to dry weight, assuming 73% water.

BIOCHEMICAL MEASUREMENTS

Blood samples were collected from each soldier prior to beginning the course, and at the completion of each of the four training phases. The fasting blood samples were collected into vacutainer tubes; all blood collections were conducted between 0430-0900 h from soldiers in the seated position. Following collection, blood samples were kept cool (approximately 15°C) until processing (completed within 4-5 hours). Serum (or plasma) and cells were separated, and the different blood fractions frozen (-20°C) until shipment on dry ice to the analytical laboratory. In all cases samples were frozen when received by the laboratory. Five blood samples (total volume of 35 ml) were taken from each soldier at each collection point to provide samples for biochemical analysis and immunological testing.

Clinical Chemistries

Blood samples were analyzed for general indicators of health and nutritional status. The following tests were performed on serum using a Beckman Synchron CX5 automated chemistry analyzer (Beckman Instruments, Fullerton, CA) with manufacturer recommended reagents.

Test	Method	Wavelength
Glucose	hexokinase/G6PDH	340 nm
Blood urea nitrogen	urease/glutamate dehydrogenase	340 nm
Sodium	ion selective electrode	
Potassium	ion selective electrode	
Chloride	ion selective electrode	
Uric acid	uricase/peroxidase	520 nm
Total protein	biuret	560 nm
Albumin	bromcresol purple	600 nm
Calcium	arsenazo III	650 nm
Phosphorus	molybdate	520 nm
Magnesium	calmagite	520 nm
Cholesterol	chol est/chol ox/peroxidase	520 nm
Triglycerides	lipase/glycerol kinase/G1PDH	520 nm
Total bilirubin	modified Jendrassik-Groff	560 nm
Lactate dehydrogenase	lactate to pyruvate	340 nm
Gamma glutamyl transferase	gamma glutamyl p-nitroaniline	410 nm
Iron	ferrozine	560 nm
Total iron binding capacity (TIBC)	$MgCO_3$/ferrozine	560 nm

Percent iron saturation was calculated using the equation: serum iron concentration/TIBC × 100. Serum β-hydroxybutyrate concentration was determined using the Beckman Synchron CX5 using β-hydroxybutyrate dehydrogenase method (Diagnostic Kit 310A, Sigma Chemical Co., St. Louis, MO). Ferritin was determined in duplicate aliquots of serum using an IRMA kit (BioRad Laboratories, Richmond, CA) with standards prepared against the First International Standard.

The following assays were conducted on plasma samples with EDTA as the anticoagulant using the Beckman Synchron CX5 automated chemistry analyzer with manufacturer recommended assay systems, unless otherwise noted.

Test	Method	Wavelength
Glycerol	glycerokinase/pyruvate kinase/LDH (Sigma)	
Lactate	lactate dehydrogenase (Sigma)	
NEFA	acyl CoA synthase/oxidase/peroxidase (Wako)	560 nm
AST	aspartic acid/α-keto glutaric acid/ malate dehydrogenase	340 nm
ALT	alanine/α-keto glutaric acid/LDH	340 nm

HDL-cholesterol was determined on EDTA-treated plasma using dextran sulfate (MW 50,000) precipitation with DMA reagent and analyzed for cholesterol on the Beckman Synchron CX5 analyzer using a cholesterol oxidase method.

Routine chemistries were verified daily by performing quality control procedures using BioRad unassayed chemistry controls and monthly comparisons were made in an interlaboratory quality assurance program. Standardization was also confirmed through participation in the College of American Pathologists Survey.

Nutritional Assessment

Selected vitamins and iron status were assessed using their respective biochemical markers as listed in Table 5, using the methods described below.

Vitamin A (retinol) was determined by HPLC using heparin plasma samples extracted into hexane after addition of B-apo8'-carotenal (internal standard) and separated with 100% methanol through an ODS Hypersil 3 μm column, with UV detection at 320 and 450 nm; recovery averaged 98%.

Table 5. Measured Blood-borne Biochemical Markers of Vitamin and Iron Status

Nutrient	Sample	Biochemical marker	Lower limits of normal
Vitamin A (retinol)	heparin	retinol concentration	> 1.05 µmol/L
Thiamin (Vitamin B_1)	RBC	in vitro stimulation of erythrocyte transketolase activity by thiamin pyrophosphate	< 15% stimulation
Riboflavin (Vitamin B_2)	RBC	in vitro stimulation of erythrocyte glutathione reductase activity by flavin adenine dinucleotide	< 40% stimulation
Vitamin B_6 (pyridoxal)	RBC	in vitro stimulation of erythrocyte glutamate oxaloacetate transaminase activity by pyridoxal-5'-phosphate	< 100% stimulation
Vitamin B_{12} (cyanocobalamin)	serum	Vitamin B_{12} concentration	> 148 pmol/L
Vitamin C (ascorbic acid)	heparin	ascorbic acid concentration	> 30 µmol/L
Vitamin D	serum	25-hydroxycholecalciferol concentration	> 32 nmol/L
Folacin	RBC serum	erythrocyte folacin concentration folacin concentration	> 360 nmol/L > 5 nmol/L
Iron	serum	total iron concentration, total iron binding capacity (TIBC), ferritin	> 10 µmol/L > 40 µmol/L > 10 µg/L

Abbreviations for blood fraction & anticoagulant: heparin = heparinized plasma, serum = untreated serum, RBC = washed red blood cells from blood collected in EDTA.

Vitamin B_{12} and folic acid were measured in EDTA plasma using a combined radioreceptor assay (BioRad). The procedure used a boiling step to eliminate interferences by endogenous binding proteins and ^{57}Co and ^{125}I were counted following competition for binding with intrinsic factor (Vitamin B_{12}) or binding proteins (folate). The same method was used for determination of RBC folate on samples treated with ascorbic acid at the time of collection.

Red cell levels of three enzyme markers of B vitamin status (Table 5) and stimulation of their activity with the addition of exogenous vitamins were based on methods developed by Bayoumi (40) and Vuilleumier (41) and adapted to the Beckman Synchron CX5. Percent stimulation was determined as:

100 × (activity with vitamin - activity without vitamin)/activity without vitamin.

These assays were performed on a hemolysate collected and preserved as follows. Red cells collected from EDTA treated blood were washed twice with normal saline and frozen until analysis. Samples were thawed and hemolyzed by adding 2 mls of cold deionized water per 500 μL of red cells. Hemoglobin was determined on the hemolysate and samples were then diluted with deionized water to achieve a final hemoglobin concentration of approximately 1 g/dL. Activity was expressed in IU/g hemoglobin.

Red cell transketolase and stimulation with thiamine pyrophosphate (TPP) were determined by performing 2 runs per sample, one on a reagent system containing TPP and the other not. The reagent system was composed of ribose-5-phosphase/xylulose-5-phosphate/triose isomerase/glycerol dehydrogenase.

Red cell glutathione reductase and stimulation with FAD were determined by performing two runs per sample, one on a reagent system containing FAD and the other not. The reagent system consisted of oxidized glutathione/NADPH and buffer.

Red cell AST and stimulation with pyridoxal phosphate were performed using 2 runs with the Beckman AST reagent cartridge, one with and the other without incubation of the sample with pyridoxal phosphate.

Vitamin C in heparinized plasma was determined on the Beckman Synchron CX5 using a method developed in-house (at Pennington Biomedical Research Center). Upon thawing, samples were treated with 50 μL of metaphosphoric acid/dithiothreitol per 500 μL of sample to stabilize the ascorbic acid. The method uses ascorbate oxidase to convert ascorbic acid to dehydroascorbic acid (DHAA), which then reacts with o-phenylenediamine (OPDA) to produce an adduct which absorbs at 340 nm. Interferences and endogenous DHAA were removed by reacting for 5 minutes at 37°C with OPDA. The reaction is then catalyzed by the addition of ascorbate oxidase and the rate of reaction followed for 5 additional minutes. The method is linear to at least

200 mg/L and recovers 94% of added ascorbic acid.

25-hydroxy-vitamin D was determined in duplicate in serum using an RIA kit (Incstar Corporation) with acetonitrile extraction. Specificity of the antibody was equal for the D2 and D3 forms; crossreactivity for 1,25 dihydroxy compounds and cholesterol were 5% and 1%, respectively.

Normal reference values were based upon ranges established in military and civilian nutritional assessment studies as specified by Sauberlich (42), unless superceded because newer methods of analysis were used (43) or because normal reference values for the laboratory at which the assays were performed (Pennington Biochemical Research Center) were different. Reference values for the vitamins measured in this study are given in Table 5.

Endocrine markers of nutritional status

Hormone assays were performed using commercially available kit procedures. All samples for an individual were processed in duplicate in the same assay batch using aliquots of serum which had been stored at -45°C for up to 6 months. Testosterone, estradiol-17β, cortisol, aldosterone, and insulin were measured by radioimmunoassay (Diagnostic Products Corp.), with interassay coefficients of variation (CV) of 7.7%, 5.4%, and 8.5% for the first 3 hormones, respectively. Insulin and aldosterone were measured only in a single assay subsample of 16 soldiers. Because of its extreme sensitivity to repeated freeze-thaw cycles, insulin was measured after a single thaw. Insulin was calibrated against 1st IRP 66/304; sensitivity was 2 μIU/ml. Sex hormone binding globulin was measured by IRMA (Farmos Group Ltd, Finland) with mouse monoclonal antibody, with interassay CV of 6.3%. Serum insulin-like growth factor-I (IGF-I) was measured in single thaw aliquots by RIA after acid ethanol extraction (Allegro, Nichols Laboratories), calibrated against WHO 1st IRP 87/518, with 14.3% interassay CV. Growth hormone was measured by an avidin coated-bead RIA with 2 mouse monoclonal antibodies (Allegro, Nichols Laboratories), calibrated against NIAMDD-hGH-RP-1, sensitivity to 0.02 ng/ml, and interassay CV of 10%. Luteinizing hormone (LH) was measured by IRMA (ICN Biomedicals, Inc), calibrated against WHO 1st IRP 68/40, with 7.0% interassay CV. Data on serum triiodothyronine, thyroxine, thyroid binding globulin, and thyroid stimulating hormone was still being compiled at the time of this report and will appear elsewhere. For this study, acceptable intraassay CVs for all assays were < 5%.

MICROBIOLOGICAL & IMMUNOLOGICAL PROCEDURES

Hematology

At each measurement period, complete blood counts (CBC) and white blood cell differential counts were obtained on a blood sample drawn into EDTA-containing vacutainers. Automated differential counts and CBCs were determined on samples from the baseline, phase I, and phase II measurement periods using a Technicon H-6000 analyzer (Technicon, Inc., Tarrytown, NY) at Martin Army Community Hospital, Ft. Benning, Georgia. Blood counting on samples collected at the end of phases III (USAF Regional Hospital, Eglin AFB, FL) and IV (William Beaumont Army Medical Center, Ft. Bliss, TX) were done using a Coulter Model STKR analyzer (Coulter Electronics, Inc., Hialeah, FL). Differential counts were not obtained on blood samples collected at the end of phase I.

Cell-mediated immune function

At each collection point, a blood sample was collected into siliconized vacutainer tubes containing sodium heparin (143 USP units) for immune studies. The blood was held at ambient temperature (18-27°C) for 24 h prior to preparation for *in vitro* cell culture. This timing was designed to equate the handling of samples from each phase by accommodating the longest period of travel between test sites and the immunology laboratory in Beltsville, Maryland. Plasma for cytokine quantitation was removed from packed cells at approximately 32 h post-collection. The plasma samples were held at -70°C until analysis.

Whole blood was diluted 1:4 and 1:2 with RPMI-1640 tissue culture medium (Sigma Chemical Co., St Louis, MO) in polystyrene tubes for lymphocyte proliferation and cytokine production cultures, respectively. The RPMI-1640 contained L-glutamine at 2.0 mmol/L and penicillin-streptomycin at 100 U/mL and 100 µg/mL, respectively. The *in vitro* cultures for proliferative responsiveness received in order: 100 µL of RPMI-1640 per well of round bottom 96-well tissue culture plates, 50 µL of RPMI-1640 alone (background) or with designated stimulant: phytohemagglutinin-M (PHA-M; 0.08 ug/µL, Sigma), conconavalin-A (ConA; 0.08 µg/µL, Sigma), pokeweed mitogen (PWM; 0.008 µg/µL, Sigma), or tetanus toxoid (TT; 0.128 Lf/µL, Connaught Laboratories International, Willowdale, Ontario, Canada), and 50 µL of blood (diluted 1:4). The cultures contained a final volume of 200 µL, with the final blood dilution at 1:16.

Proliferative activity in vitro was based on mean DNA incorporation of tritiated thymidine (methyl-^{3}H; specific activity 6.7 Ci, 248 GBeq/mmol, New England Nuclear, Boston, MA) by cells in triplicate cultures without (background) and with stimulant. PHA-M and ConA were added to the cultures at 4 µg, and PWM at 0.4 µg, per culture. TT was added to the cultures at 6.4 limits of flocculation (Lf) per culture. Cell cultures stimulated with PHA-M and ConA were incubated for 72 h, and those stimulated with PWM and TT for 144 h, at 37°C in a 5% CO_2, 95% humidified air incubator. ^{3}H-thymidine (1.0 uCi; 37 KBeq) was added to each culture 24 h prior to termination, after which cells were harvested, the ^{3}H-thymidine labeled DNA was collected on 12-well filtermats (Skatron Inc., Sterling, VA), 4.5 mL of scintillation fluid (Ready-Safe, Be[illegible]man) was added to each vial containing individual filter discs, and the vials were co[illegible]ed (Beckman LS 3801 scintillation counter). Proliferation activity of lymphocytes is expressed as corrected dpm (stimulated minus background).

For cytokine production the cultures received the same treatment as the proliferative activity cultures, with PHA-M, ConA, or PWM stimulants but with 50 µL of blood diluted 1:2 instead of 1:4.. The cultures also contained a final volume of 200 µL, but with the final blood dilution at 1:8. The cell cultures were incubated similarly to those for lymphocyte proliferation, except for 48 instead of 72 h for PHA-M and ConA-stimulated cultures, and 96 instead of 144 h for PWM-stimulated cultures. The supernatants from each set of triplicate cultures were collected, pooled, and stored at -70° C until assayed. A summary of the blastogenesis and interleukin assays conditions is given in Table 6.

Variables	Blastogenesis	Interleukins
Blood	12.5 uL/well*	25 uL/well
RPMI-1640	187.5 uL/well	175 uL/well
PWM	0.4 ug/well	0.4 ug/well
Time	6 d	4 d
PHA&ConA	4.0 ug/well	4.0 ug/well
Time	3 d	2 d
Tetanus	6.4 Lf/well	6.4 Lf/well
Time	6 d	4 d
Assay	3H-TdR	ELISA

*Round bottom plate

Table 6. Cell culture conditions for immune function studies.

Cytokine interleukin-2 (IL-2) was determined in

supernatants from unstimulated and PHA-M-stimulated cultures by a commercially available ELISA (Dupont Boston, MA). Cytokine interleukin-6 (IL-6) was determined in supernatants from unstimulated cultures and plasma by ELISA test kits (Clinigen, R&D Systems, Minneapolis, MN). Soluble IL-2 receptors (IL-2R) were determined in supernatants from PHA-M stimulated cultures using the CELL-FREE Interleukin-2 Receptor Test Kit (T-Cell Sciences, Inc., Cambridge, MA).

Delayed skin hypersensitivity test

Changes in the ability of soldiers to express an in vivo immune response was assessed by administering a delayed skin hypersensitivity test (Multitest-CMI, Connaught Laboratories, Inc., Swiftwater, PA) to each soldier during the baseline measurement period, and at the end of training phases III and IV. It contained a glycerin negative control and seven antigens of culture filtrate from the following microorganisms: Clostridium tetani (tetanus toxoid), Corynebacterium diphtheriae (diphtheria toxoid), Streptococcus, Group C (streptococcus), Mycobacterium tuberculosis (tuberculin, old), Candida albicans (candida), Trichophyton mentagrophytes (trichophyton), and Proteus mirabilis (proteus).

The tine tests were applied to the ventral forearm of each soldier in the morning, but after blood samples had been taken. After forty-eight hours, the response to each antigen was determined by measuring the diameters (parallel and perpendicular to the long axis of the forearm) of the induration resulting at each of the eight tine administration sites. The site was recorded as a positive reaction when it showed an induration of 2 mm in diameter or more, compared to the negative control.

Nasopharyngeal and nasal microbiological cultures

Nasopharyngeal (throat) and nasal swab specimens were obtained from each soldier at each measurement period in order to monitor relative changes in the prevalence of carriers of Group A β-hemolytic Streptococcus (throat) and S. pneumoniae (nasal). Nasal and nasopharyngeal swabs were obtained from each soldier at the beginning of the course (prior to penicillin G prophylaxis; Bicillin LA, Wyeth Laboratories, Philadelphia, PA) and at the end of each of the four training phases. Throat swabs were collected from each soldier using rayon tip swabs (Precision Bioport 6, Precision Dynamics Corporation, San Fernando, CA) with Modified Stuart's medium and cultured to determine the presence of Group A β-

hemolytic Streptococci. Nasal swabs were collected using calcium alginate swabs (Calgiswab Type 1, Spectrum Laboratories, Inc., Houston, TX) with Modified Stuart's medium, and cultured to identify the presence of S. pneumoniae.

The bacteriology was performed by clinical laboratories at the nearest military medical treatment facility in each phase (Martin Army Community Hospital, Fort Benning, GA; USAF Regional Hospital, Eglin Air Force Base, FL; William Beaumont Army Medical Center, Fort Bliss, TX). Each swab was inoculated onto separate petri dishes containing Trypticase Soy agar with 5% sheep blood (BAP)(Becton Dickinson Microbiological Systems, Cockeysville, MD) or Strep A Isolation agar (Remel, Lenexa, KS). The BAP was used for isolation of S. pneumoniae while the Strep A Isolation agar enhanced the recovery and identification of β-hemolytic Streptococci. The plates were incubated 18-24 hours at 35 °C in an atmosphere of 5% CO_2. Isolates were identified using standard bacteriological methods (44,45).

PHYSICAL EXAMINATION

A physician conducted a visual examination of each soldier (in the nude) at the completion of the study in order to ascertain the presence of any outward clinical signs of malnutrition or nutrient deficiencies. The examination emphasized jaundice, cheilosis, glossitis, edema, and history taking. Such general clinical assessment has been reported to be reproducible and valid in comparison to laboratory measurements such as delayed cutaneous hypersensitivity, changes in blood albumin and transferrin levels, and body composition (46). This exam was repeated for a few of the volunteers six months after the end of the course, as reported in Appendix IV.

STATISTICAL ANALYSIS

Of the original 190 Ranger trainees which comprised the sample for baseline measurements, 55 remained to provide final measurements. For most measurements, only data from these trainees are reported. However, some data collected from soldiers who left the class at earlier stages are reported when the data provides useful comparisons; these instances are specifically noted in the text. The data were analyzed using a one-way repeated measures analysis of variance, and means within the test population were compared across time using paired t-tests using SPSS-X (47). A Scheffe's multiple range test was used in some instances to make more comprehensive comparisons between sampling intervals; differences are indicated by dissimilar letters. Tabular data are reported as means±standard deviation.

RESULTS & DISCUSSION

MEDICAL ATTRITION

Of the 190 subjects who started in the study, 33 (17%) completed the Ranger course without recycling a phase. Another 47 soldiers from our original study group graduated with the following class in November, and 10 graduated in December, for an overall success rate of 47% for our study group.

Grouped according to their pre-Ranger training origin, the soldiers sent by Ranger units had a higher overall success rate, and Lieutenants sent from Officer Basic Courses had a lower overall success rate, compared to the average (Table 7).

Table 7. Success rate by pre-Ranger training origin.

Source	Pass	Total	Success rate
Officer basic courses	7	20	35.0%
Fort Benning GULAG (recycles)	17	39	43.6%
Other units	46	97	47.4%
Ranger units	20	34	58.8%
Total	90	190	47.4%

Academic failures accounted for the majority of drops and recycles from the class (69%), with medical problems accounting for 25% of this group (Table 8). These results are shown by phase in Figure 2. Medical withdrawals from the class resulted most often from orthopedic injuries (including 2 fractures and 3 stress fractures) and heat injuries. Infections accounted for less than 13% of all medical withdrawals. At least 13 of the 39 medical withdrawals were recycled into the next class, including 4 out of the 5 cellulitis infections and 7 traumatic injuries; eleven of these medically recycled soldiers graduated in one of the next 2 classes. Nearly all heat injuries and withdrawals for blisters and other foot problems occurred during the RAP. Many of the orthopedic injuries, including both fractures and 1 of the 3 stress fractures documented in this class, occurred during mountain training. Withdrawals for cellulitis occurred primarily during the jungle phase (Table 8).

Table 8. Reasons for class attrition (drops and recycles) at each phase of Ranger training.[1] Of this group, 36% successfully recycled and graduated with one of the next 2 classes, bringing the course success rate to 47%.

Category	RAP	I	II	III	IV	Total
Medical (total)	**21**	**2**	**7**	**7**	**2**	**39**
---heat injury	9	1				(10)
---feet/blisters	5					(5)
---orthopedic injuries	4		6	3	1	(14)
---cellulitis			1	4		(5)
---eye injury	2				1	(3)
---72 h profile	1	1				(2)
Academic/RAP testing[2]	44	8	22	6	21	101
Peer evaluation		1	1	2		4
Special Obs Report (SOR)			2		2	4
Lack of motivation (LOM)	1	1	1	1		4
Administrative	2	1	1	1		5
Total attrited	**68**	**13**	**34**	**17**	**25**	**157**
Total starting phase	**190**	**122**	**109**	**75**	**58**	**33 grads**
Total available for study[3]	**---[4]**	**109**	**93**	**68**	**55**	**---**

[1]RAP=Ranger Assessment Phase, I=Benning, II=mountains, III=jungle, IV=desert.

[2]During the RAP, academic withdrawals included failures on the Army Physical Fitness Test (6), Combat Water Survival Test (3), 5-mile run test (4), 8-mile footmarch test (13), day/night land navigation (15), and military skills test (3).

[3]This includes some of the soldiers who were recycled for the phase, i.e. this may include more soldiers than the number starting the next phase. Thus, 55 soldiers of 58 soldiers who advanced to the desert phase were studied at the end of the phase (2 SORs and 1 medical recycle had already been separated from the group); however, only 33 graduated and the other 22 studied were recycled in the desert phase.

[4]No data were collected at the end of the 4-day RAP phase, other than reasons for attrition.

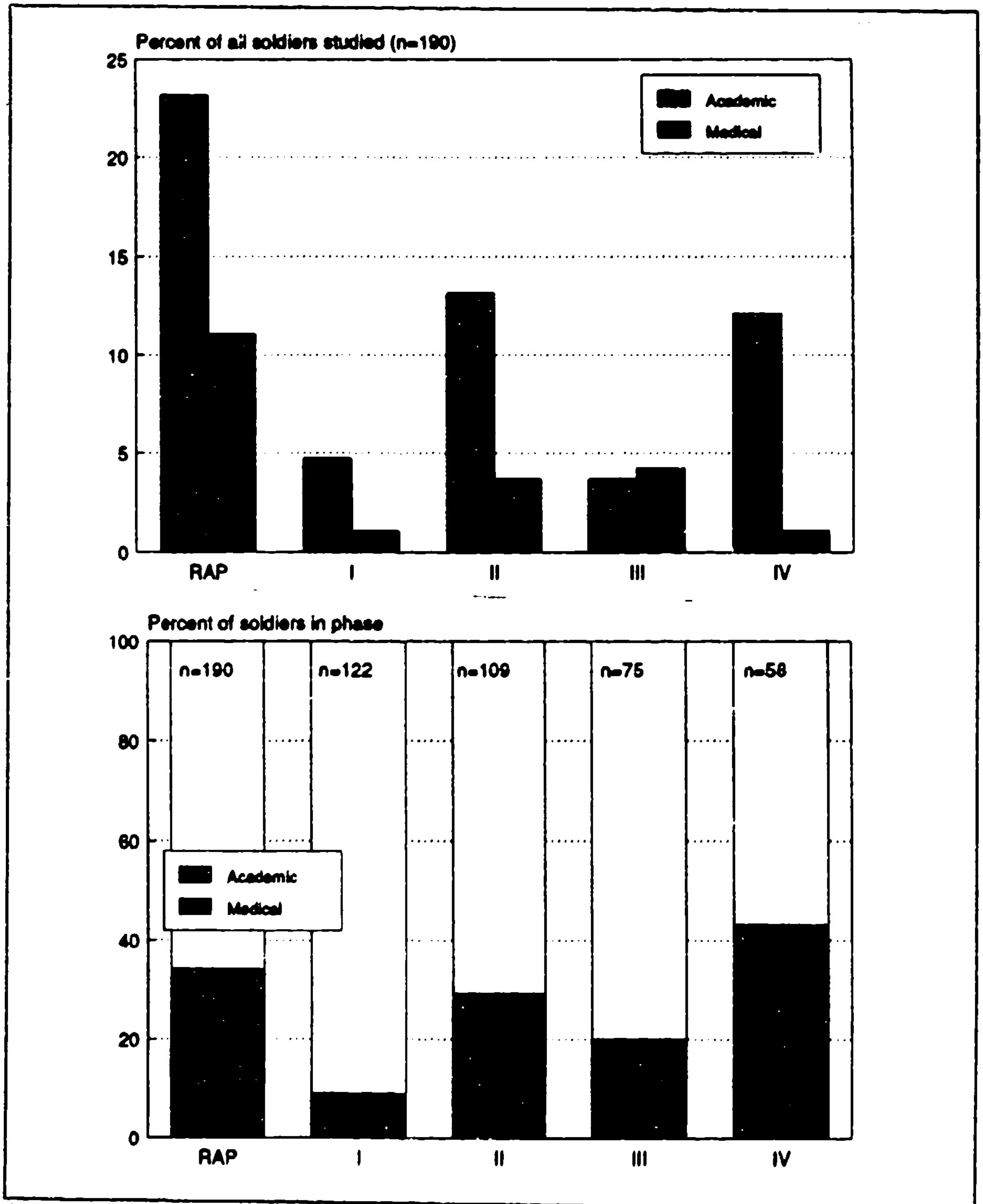


Figure 2. Percent of soldiers attrited or recycled for academic and medical reasons, expressed as percent of all soldiers studied (upper graph) and as percent of soldiers still present in each respective phase (lower graph).

The reasons for attrition from the course, the volunteers who ultimately left the course without successfully completing the requirements for the Ranger tab, are summarized in Table 9. This represents a subset of the group summarized in Table 8, with the recycled study volunteers who were eventually successful subtracted out. After the 4-day RAP, cellulitis in the jungle phase and orthopedic injuries in the mountain phase were the predominant medical causes of attrition.

Certain medical problems, usually common within a specific training phase, primarily received self-treatment and tended to escape treatment documentation by the medics. These problems included chigger bites and poison ivy dermatitis during phase I, severe abrasions on the bony processes of the back caused by the combination of friction, moisture (rain), and pressure from the rucksack ("ruck rash") during the mountain phase, and complaints of back strain towards the end of the jungle training phase. Foot problems were common to all phases of the training.

Table 9. Reasons for <u>course</u> attrition, as in Table 8, except without those recycled soldiers who graduated in the next 2 classes.

Category	RAP	I	II	III	IV	Total
Medical (total)	**18**	**2**	**5**	**3**	**0**	**28**
---heat injury	9	1				(10)
---feet/blisters	4					(4)
---orthopedic injuries	4		5	1	0	(10)
---cellulitis			0	2		(2)
---eye injury	0				0	(0)
---72 h profile	1	1				(2)
Academic/RAP testing	33	7	13	1	7	61
Peer evaluation		1	1	0		2
Special Obs Report (SOR)			1		1	2
Lack of motivation (LOM)	1	1	1	1		4
Administrative	2	0	1	0		3
Total attrited	**54**	**11**	**22**	**5**	**8**	**100**

INFECTION RATES

The end-of-phase review of medical records for the mountain, jungle and desert phases revealed that 13 (39%) of the soldiers who completed the course without recycle had been treated with antibiotics for infection. The majority of these infections involved cellulitis of the lower extremities, usually cellulitis (and/or bursitis) of one or both knees. The prevalence of clinically significant infections markedly increased from 8% (9/109 soldiers) in the mountain phase, to 25% (19/75) and 24% (14/58), in jungle and desert phases, respectively (X^2 test; $p<0.01$)(Table 10).

The prevalence of Group A β-hemolytic Streptococcus carriers in this study was low (Figure 3). Before the penicillin prophylaxis, the prevalence was 3% (6/186) and this varied from 2% (2/117), at the end of the first phase, to 5% (3/56) at the end of the course. There were no reported cases of Streptococcal pharyngitis in the course.

Table 10. Infections documented in medical records which were treated with antibiotics during the last 3 phases of training.

Type of Infection	Mountain (phase II)	Jungle (phase III)	Desert (phase IV)
Cellulitis			
--knees	3	8	6
--leg		1	
--ankle/feet	3	2	2
--hand	1	1	
--multiple or unspecified	2		
Folliculitis - legs		3	
Eye infection		1	
Respiratory/airways infection		3	4
Other infection			2
Total/number of soldiers in phase	9/109 (8%)	19/75 (25%)	14/58 (24%)

The prevalence of S. pneumoniae carriers was also low, but rose significantly during the course. The prevalence of S. pneumoniae was 1% before the penicillin prophylaxis (2/186), and at the end of the first phase (1/117), but the infection rate increased significantly (X^2 test, $p<0.05$) during the mountain, jungle, and desert phases, peaking at 11% (8/70) in the jungle training phase. There were no cases of pneumococcal pneumonia reported during the course.

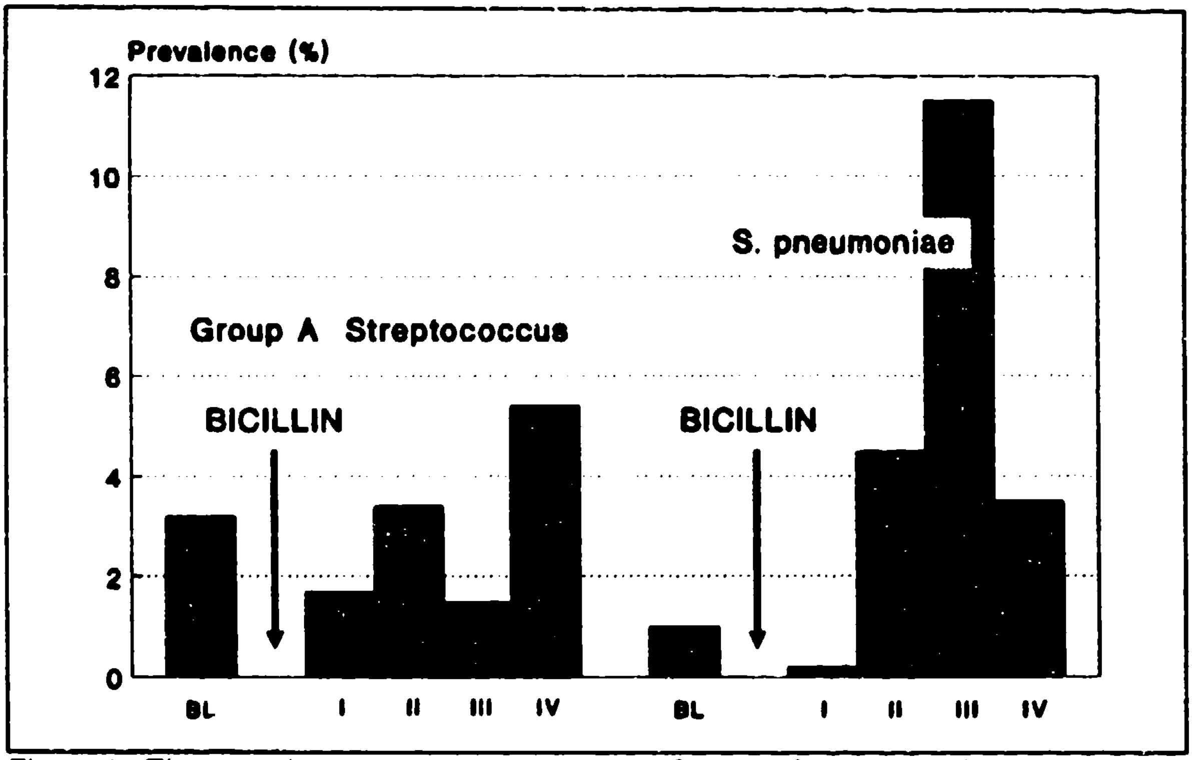


Figure 3. The prevalence of positive cultures of Group A β-hemolytic Streptococci and Streptococcus pneumoniae before (BL=baseline) and at the end of each phase of Ranger training.

BODY COMPOSITION

Body fat was the only physical measurement made in this study which had any relationship to success in the course (Figure 4). Soldiers who began the course between 10 and 15% body fat were more likely to be successful than fatter and leaner soldiers; however, soldiers with body fat spanning the entire range of the sample starting the Ranger course were successful. This only suggests that the average young soldier who is physically fit and prepared for Ranger training tends to fall in the

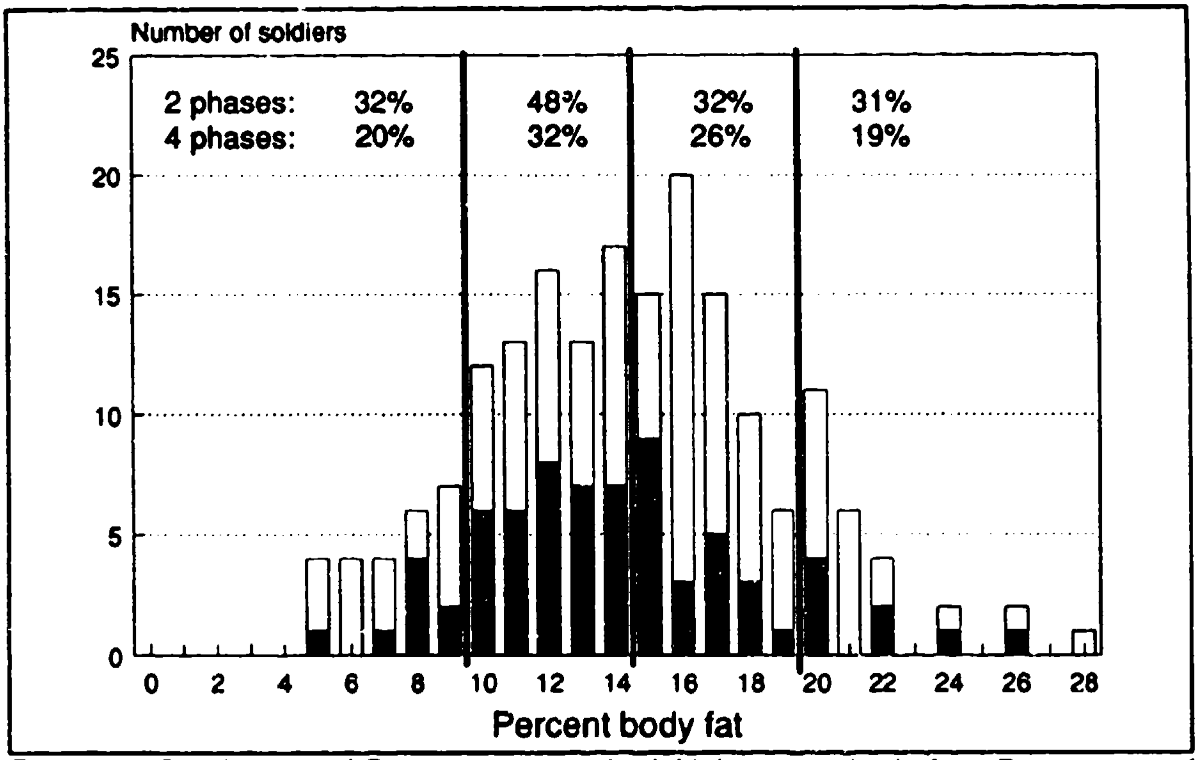


Figure 4. Distribution of Ranger students by initial percent body fat. Percentage of soldiers comple‘ng half of the course (2 phases)(solid bars) and finishing (4 phases)(open bars) are given for 5% body fat intervals.

range of 10-15% body fat. Fatter soldiers and those who are excessively lean may be less likely to be in peak fitness although body fat outside of the 10-15% range does not preclude success in the Ranger course. In fact, the fatter but fit soldiers in this study appeared subjectively to be better off towards the end of the course. Body fat was the only physical measurement which was different between the unit of origin for soldiers in this study, with the lowest body fat measured in soldiers from Ranger units (13.4±4.3% body fat), recently arrived from a three week physically intensive Ranger Indoctrination Program and highest in soldiers recently arrived from their Officer Basic Course (17.0±4.8% body fat).

The difference between these two groups in their preparation for the Ranger course and in their motivation to succeed, both of which appeared to be better in the soldiers from Ranger units, almost certainly explains some of the differential success in the course. Since the officers were not following an intense training regimen, unlike the Ranger unit soldiers, and were fatter as a group, some of the apparent relationship between fatness and success in the course may be only coincidental.

Body weight declined by 12.1±3.4 kg (range of weight loss: 6.5 to 20.6 kg) during the course (data shown as a distribution in pounds of weight lost in Figure 5). The upper limit of safely attainable weight loss recommended by clinicians for overweight patients is 2 pounds per week (e.g. AR 600-9). In the Ranger course of just over 8 weeks duration, this would amount to approximately 16 pounds; this was the lower limit of weight loss for soldiers in this study. This weight loss represented 15.6% of initial body weight and all but two of the 55 finishers lost more than 10% of their initial body weight (Figure 6). The body weights at each phase for trainees who finished compared to those who did not finish is shown in Figure 7. There was no difference between mean body weights of finishers and nonfinishers at any phase.

Percent body fat declined from 14.6±4.2% (range 6-26%) at the start of the course to 6.9±2.7% (range 4-14%) and 5.8±1.8% (range 4-12%) at the end of the 3rd and 4th phases, respectively (Table 11, Figure 8). The apparent lower body fat limit of 4% corresponded to a lower limit of approximately 3.5 kg of fat, as the mass estimated either from the DEXA measurements or calculated from the percentage body fat obtained from the ratio of the attenuation of the two energies (r-value)(28) and body weight. Ranked by initial mass of body fat, only the fattest soldiers (initial fat weight > 12.5 kg) had greater than 5 kg of fat at the end of the course; these soldiers had continued to lose the largest amounts of fat during phase IV (Figure 9). Most of the soldiers achieved an apparent minimal level of 3.5 kg of body fat. This appears to represent "essential" rather than "storage" fat, the minimal amount of fat necessary for life which makes up structural components such as cell membranes and nerve sheaths and some protective structures such as the perirenal fat.

Skinfold thicknesses at the four sites measured declined significantly from beginning to end (Figure 10). The sum of four skinfolds was not different between finishers and non-finishers at any phase (Figure 7). The skinfold thickness measurement had reached a plateau by the end of phase III and corresponded to a minimum skinfold thickness (i.e. no available subcutaneous fat) in six soldiers who had already reached an apparent minimum of body fat at the end of phase III. This minimum totaled 17-18 mm or 2.7, 3.7, 4.2, and 5.6 mm for the biceps, triceps, subscapular, and suprailiac skinfold thicknesses, respectively. The Durnin-Womersley body fat equation for young males yields a density of 1.085 for these lowest skinfold values, or 6.1% body fat. The lowest value obtained by Durnin & Womersley from 92 men aged 20-29 was 16 mm, corresponding to 5% body fat by hydrostatic weighing (27). The mean values and changes in skinfold thicknesses are shown in Table 12.

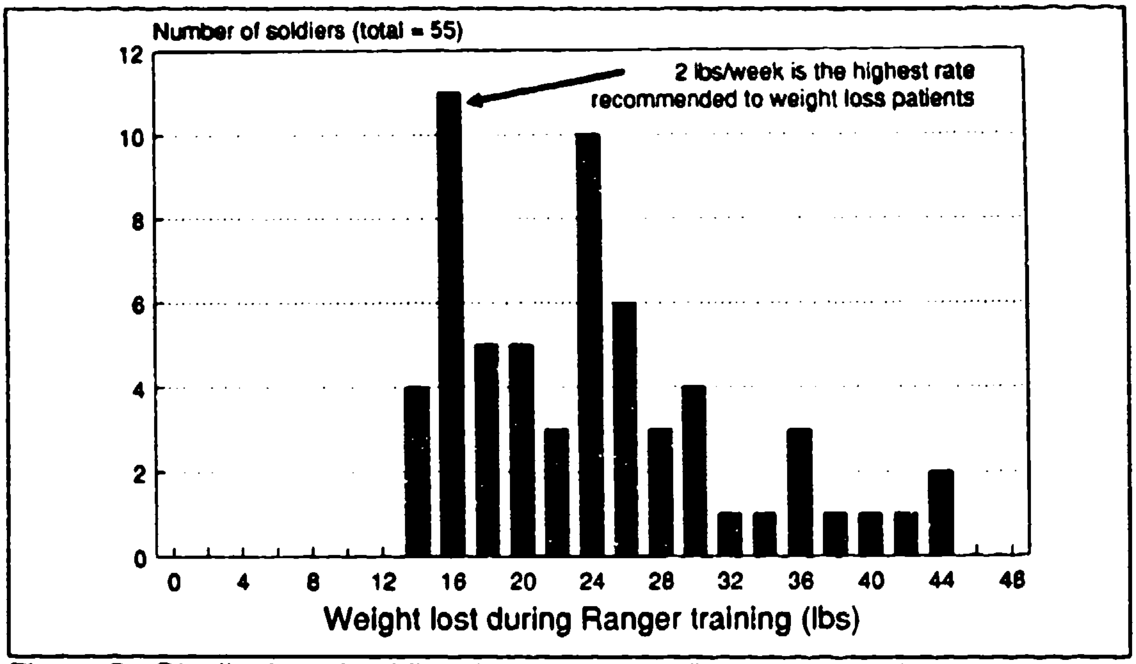


Figure 5. Distribution of soldiers by weight loss (in pounds) during the course.

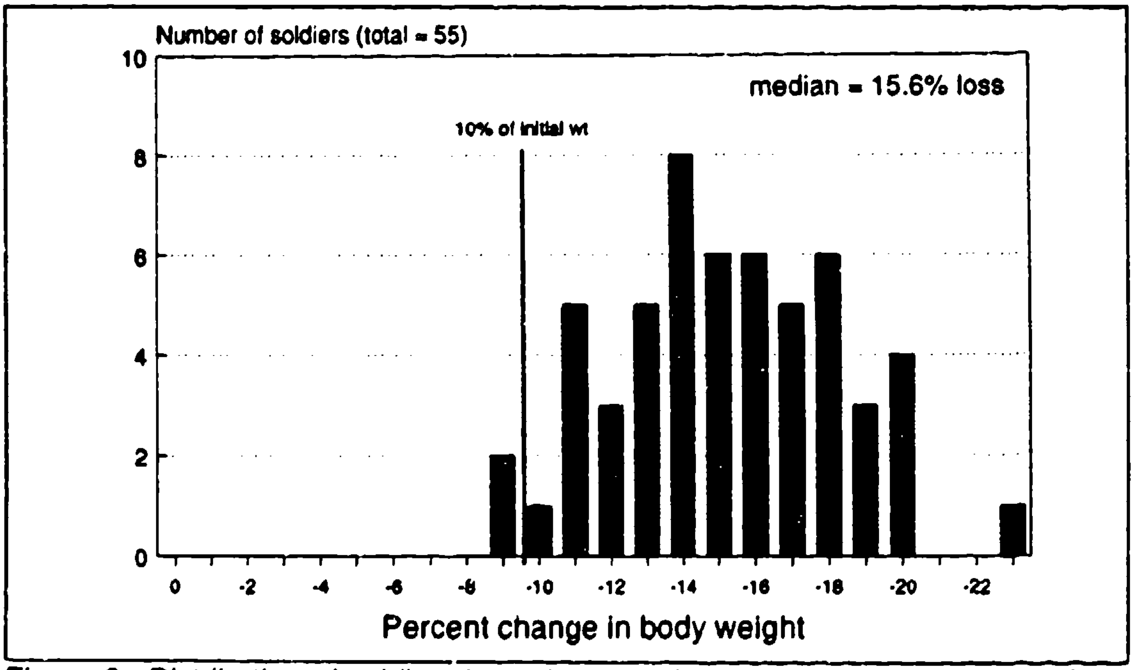


Figure 6. Distribution of soldiers by weight loss (as percent of initial body weight) during the course.

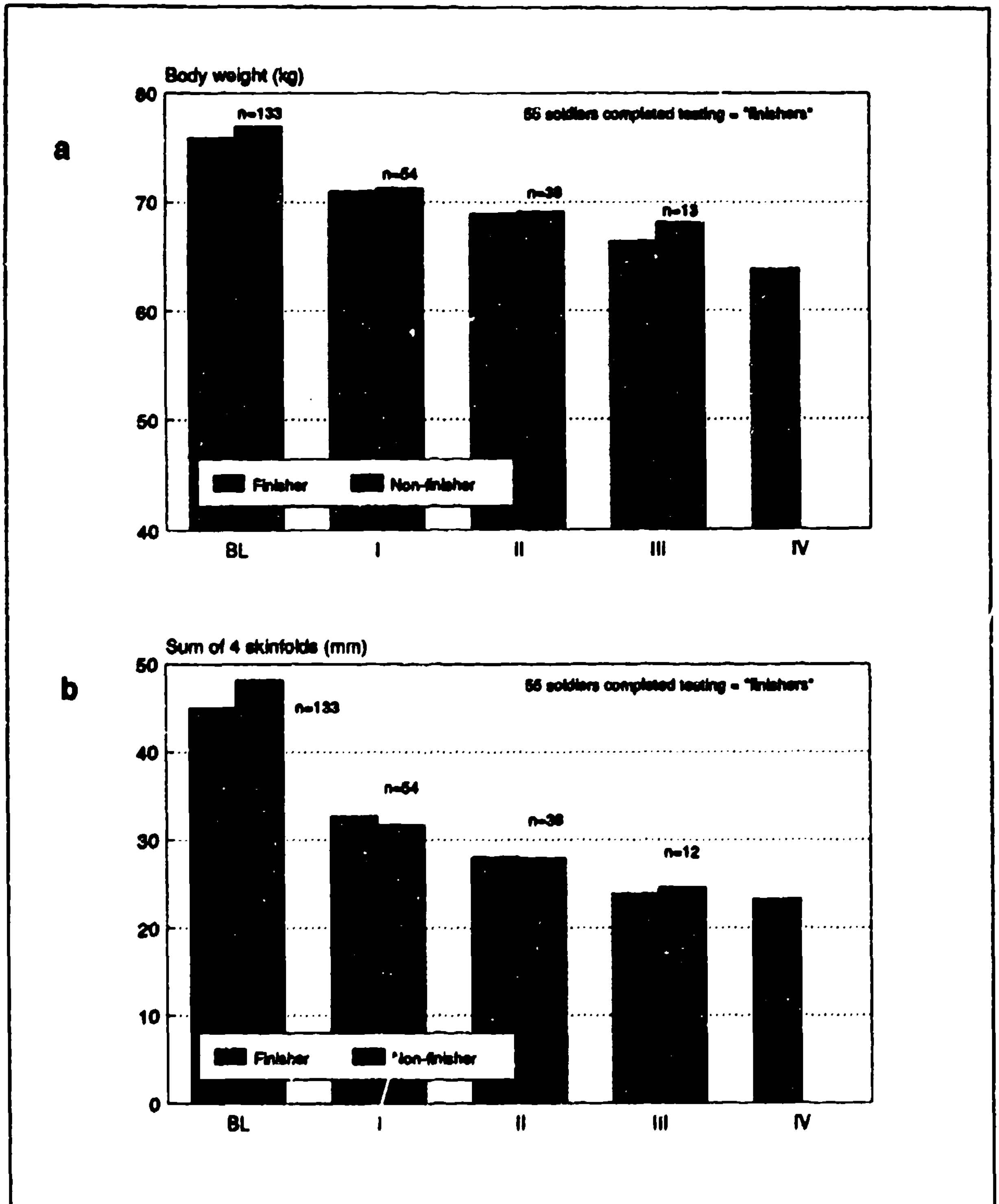


Figure 7. Body weight (a) and sum of four skinfold thicknesses (b) of nonfinishers still remaining in the Ranger course at the end of each training phase, compared to finishers.

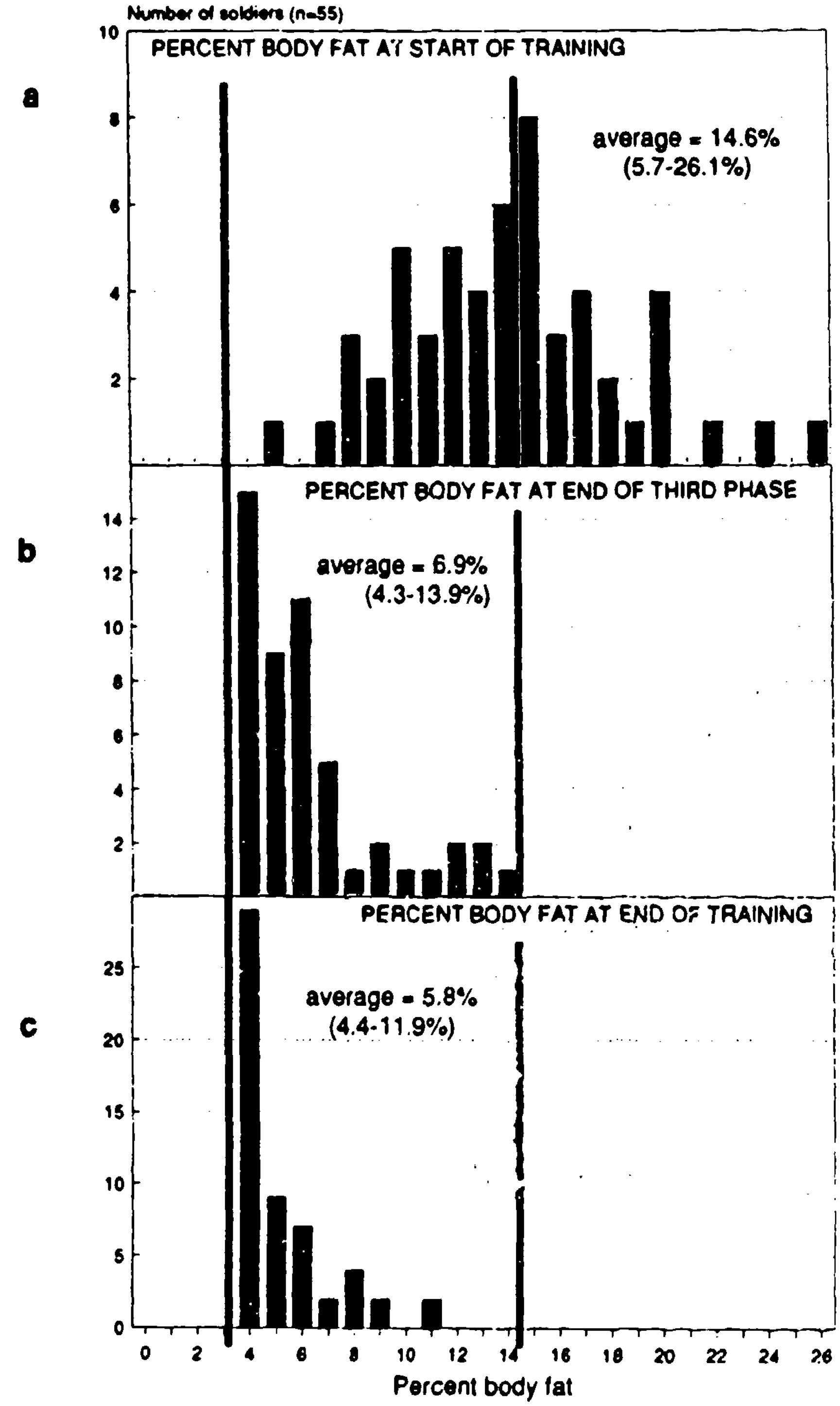


Figure 8. Distribution of finishers by percent body fat at the start of the Ranger course (a), at the end of the third phase (b), and at the end of the course (c).

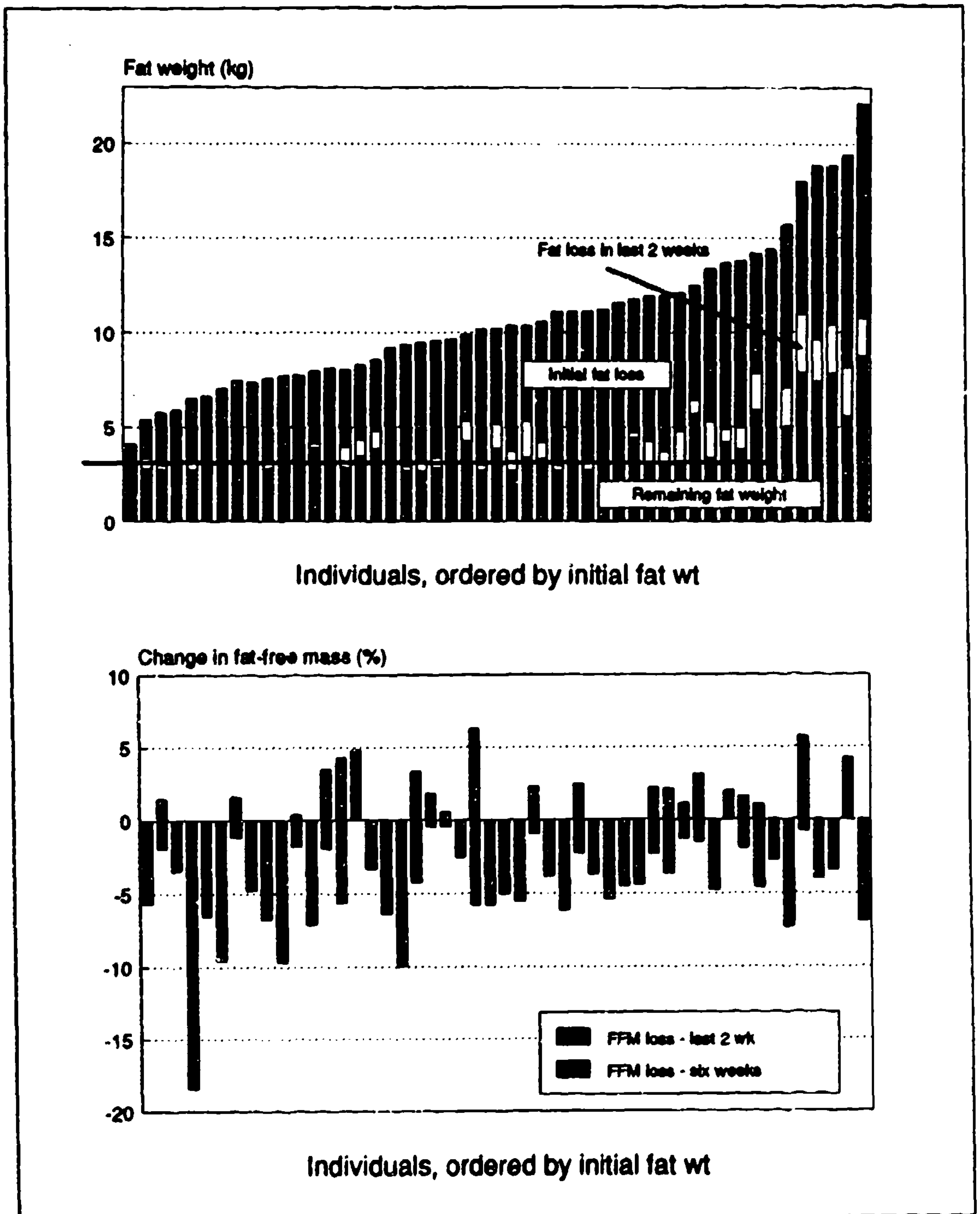


Figure 9. Fat weight of individuals ranked by initial fatness, showing the fat lost in the first 3 phases and additional fat lost in the last phase of training (upper graph) and relative changes in FFM for the same individuals (lower graph).

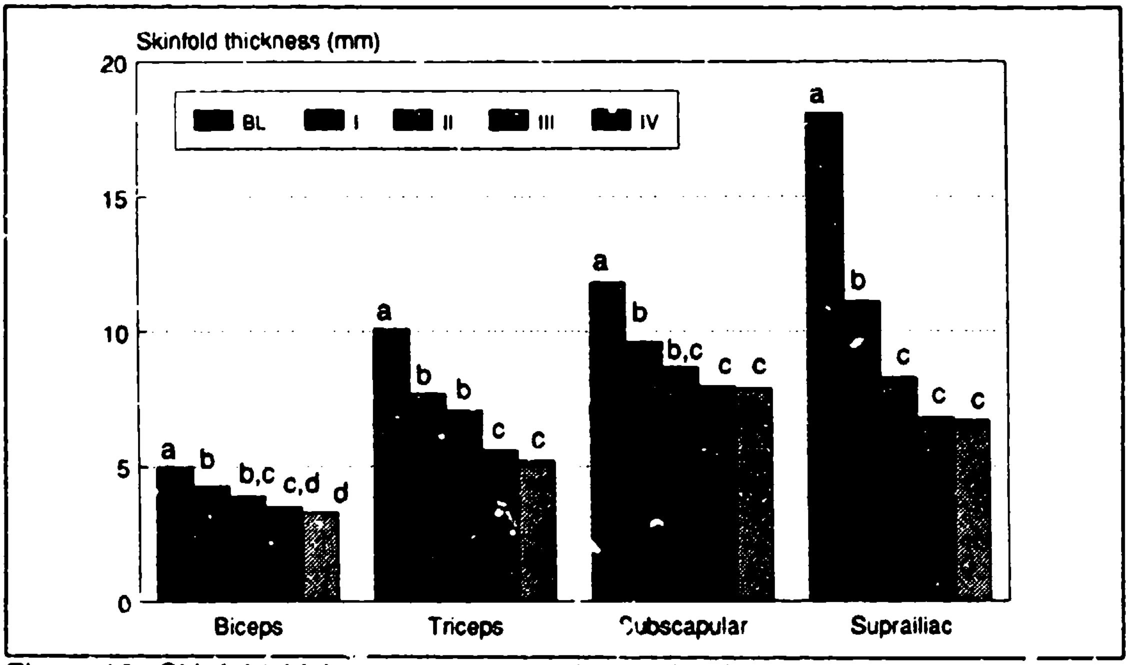


Figure 10. Skinfold thicknesses measured at the beginning and end of each phase of training. Bar height represents group mean (n=55); significant differences are designated by letters (Scheffe's test).

Of seven circumference measurements made, the neck and flexed biceps measurements changed the least, while the abdominal measurement and right thigh measurement changed the most, both in absolute and relative terms (Figure 11). The changes in shoulder and chest were intermediate in magnitude. The impact of these changes in circumference measurements on the estimate of body fat by the Army equation are shown in Table 11.

Fat-free mass declined by 4.6 $\pm$2.6 kg (6.9$\pm$3.6% of initial values); only a relatively small portion of this loss occurred in the last 2 week phase: -0.3$\pm$1.5 kg, with some soldiers actually gaining or regaining fat-free mass during this last phase. Some of the largest losses occurred in soldiers starting the course with the lowest body fat reserves (Figure 9). One outlier was remarkable for a decline in FFM which approached 20% and he looked particularly emaciated at the end of the course.

Figure 12 summarizes the mean body composition values as measured through the course with body weight and by DEXA. There was no measureable decline in the mean bone mineral content (Table 11) although 6 soldiers demonstrated a decline of 140 to 180 g, values which are well outside the error of the method.

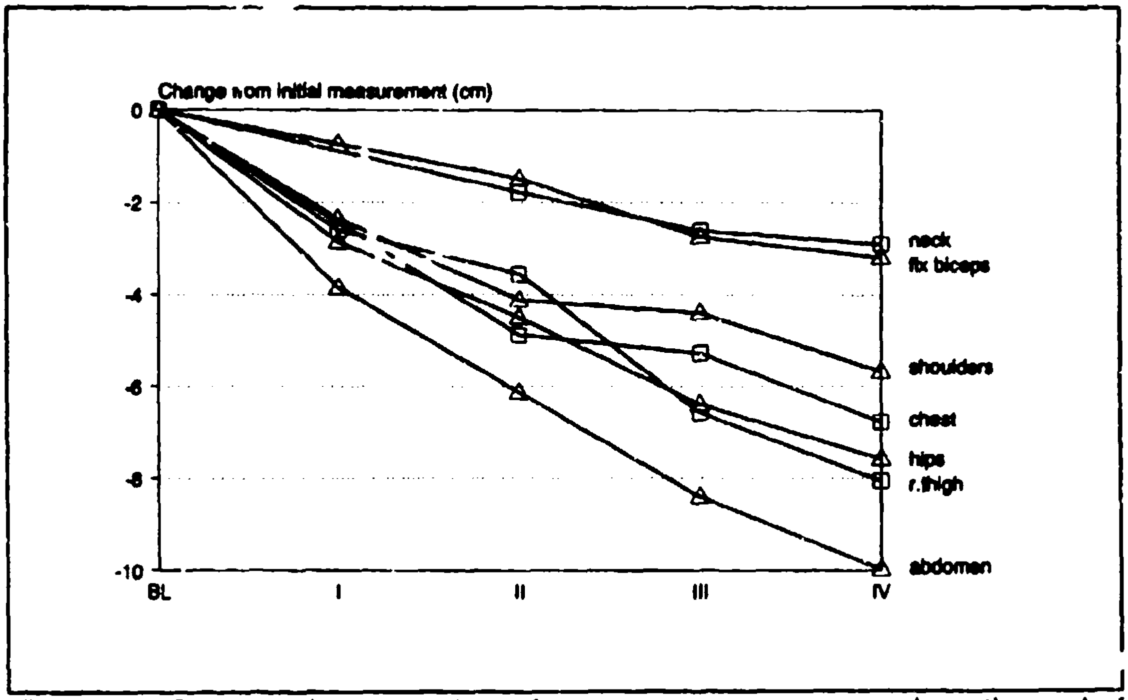


Figure 11. Relative change in circumference measurements made at the end of each phase of training, compared to starting measurements.

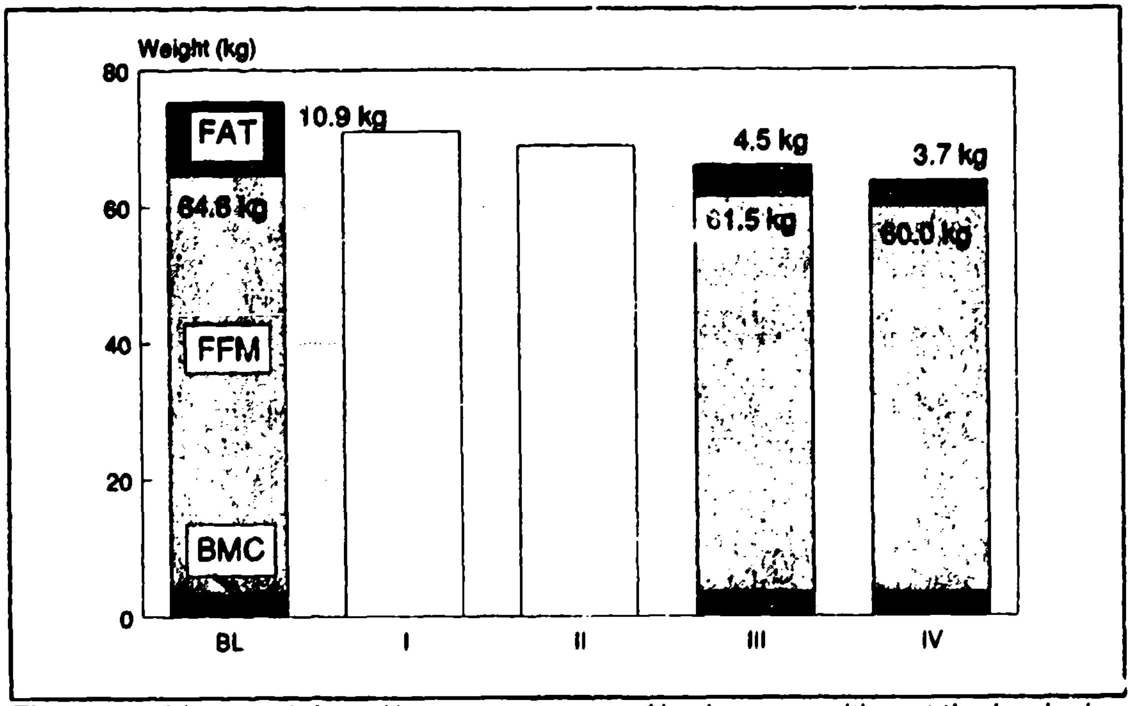


Figure 12. Mean weights of key components of body composition at the beginning of training and at the end of phases III & IV. BMC = bone mineral content.

Table 11. Body Composition of Soldiers During the Ranger Training Course[1,2]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	55	52	52	52	55
Body weight (kg)	75.9±9.0	71.0±8.0*	68.9±7.6*	66.4±7.2*	63.8±6.7*
Body fat$_{DEXA}$ (%)	14.6±4.2	----	----	6.9±2.7*	5.8±1.8*
Body fat$_{skinfld}$ (%)[3]	17.2±2.9	13.5±2.7*	11.7±2.2*	9.9±2.1*	9.5±2.2*
Body fat$_{AR\ 600\text{-}9}$ (%)[3]	15.1±3.3	----	(12.0±2.5)[4]	10.9±2.5*	9.4±2.6*
Fat weight (kg)	11.3±4.3	----	----	4.6±2.2*	3.8±1.5*
Fat-free weight (kg)	64.6±6.4	----	----	61.5±5.9*	60.0±5.8*
Bone mineral (kg)	3.50±0.41	----	----	3.48±0.40	3.45±0.40
Bone mineral density (g/cm^2)	1.29±0.08	----	----	1.29±0.08	1.28±0.08
Bone mineral /fat-free mass (%)	5.42±0.34	----	----	5.76±0.32	5.74±0.35

[1]Mean±standard deviation.
[2]Significantly different from baseline: $^{\dagger}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3]Body fat estimations based on underwater weighing-derived equations for sum of 4 skinfold thicknesses (27) and based on height and neck & waist circumferences (IAW AR 600-9).
[4]Subset sample of only 12 soldiers, because of limited testing time.

Table 12. Anthropometric Measurements of Soldiers During the Ranger Training Course[1,2]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	55	52	52	52	55
Skinfold thicknesses (mm)					
Biceps	5.0±1.2	4.3±0.8*	3.0±0.7*	3.5±0.5*	3.3±0.5*
Triceps	10.1±2.5	7.7±1.6*	7.1±1.4*	5.6±1.2*	5.2±1.2*
Subscapular	11.8±3.2	9.6±2.2*	8.7±1.7*	8.0±1.6*	7.9±1.6*
Suprailiac	18.1±6.1	11.1±4.4*	8.3±2.3*	6.8±1.7*	6.7±1.7*
Sum of 4 skinfolds	45.0±11.5	32.7±7.9*	27.9±5.4*	23.9±4.5*	23.1±4.4*
Subscap/triceps index	1.19±0.26	1.27±0.26	1.24±0.20	1.47±0.27*	1.54±0.27*
Circumferences (cm)					
Neck	38.1±1.6	----	36.5±1.1*[3]	35.5±1.3*	35.3±1.3*
Flexed biceps	33.7±2.2	33.0±2.1	32.2±1.9*	31.0±1.7*	30.5±1.9*
Shoulders	115.5±4.7	113.1±4.5	111.3±5.1*	111.1±4.0*	109.8±4.2*
Chest	100.5±5.0	----	95.6±4.7*[3]	95.2±4.1*	93.7±4.0*
Hips	95.5±4.6	92.7±4.3*	91.0±4.2*	89.1±3.8*	87.9±3.4*
Right thigh	58.2±3.9	55.6±3.7*	54.7±6.3*	51.7±3.4*	50.2±3.3*
Abdominal	82.4±5.9	78.6±5.9*	76.3±5.1*	74.0±4.3*[4]	72.4±3.9*
Waist-to-hips ratio	0.86±0.04	0.85±0.05	0.84±0.04**	0.84±0.04**	0.82±0.03**

[1]Mean±standard deviation.
[2]Significantly different from baseline: * $p<0.05$.
[3]At the end of the mountain phase, a limited number of subjects were assessed: neck, n=12; chest, n=24.
[4]Mean adjusted with removal of values for 13 soldiers who were postprandial (with marked abdominal distension).

STRENGTH MEASUREMENTS

Maximal lift capacity was markedly reduced at the end of the third and fourth phases but there was no significant decline in grip strength or grip endurance (Table 13). Maximal lift capacity declined by an average of 40 pounds, from a median value of 170 pounds to 140 pounds at the end of phase III, and 130 pounds at the end of phase IV (Figure 13). This lower value achieved at the end of the Ranger course is the average weight lifted by new Army recruits (based on a sample size of approximately 2,000 young males).

Maximal lift capacity correlated significantly with fat-free mass at the beginning (r=0.64) and at the end of the course (r=0.49). The change in fat-free mass was also highly correlated with the change in lift performance (r=0.49)(Figure 14). While the mean values for maximal grip strength did not change during the course, there were also significant correlations between fat-free mass and maximal grip strength pre (r=0.37) and post (r=0.40) and between the change in fat-free mass and change in maximal grip strength (r=0.31)(Figure 14).

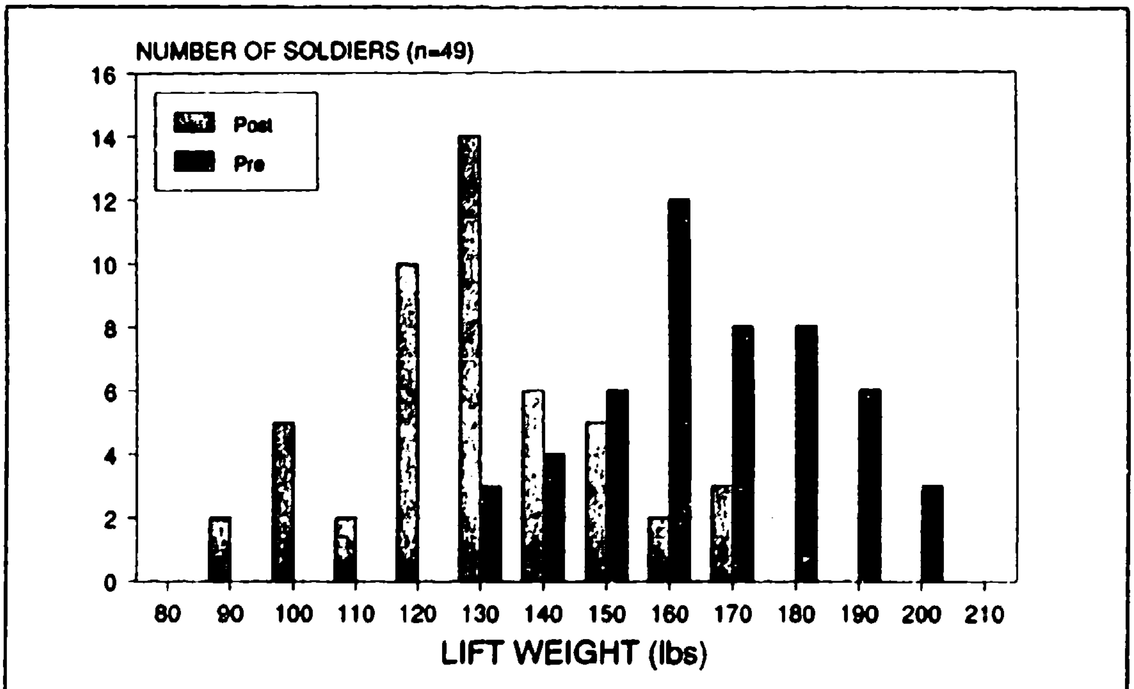


Figure 13. Distribution of maximal lift performance at the beginning (solid bars) and at the end (shaded bars) of Ranger training. The median value of 130 pounds lifted at the end of the course is the average for new male Army recruits.

Table 13. Measurements of Physical Performance of Soldiers During the Ranger Training Course[1,2,3]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	55	52	52	50	55
Maximal lift capacity (kg)	77.4±9.6	----	----	61.8±8.2**	58.7±8.9**
Maximal grip strength (N)	530±57	----	----	----	529±63
Grip holding time (s)	----	74.9±16.9	72.8±20.7	75.4±20.3	72.4±22.9
Grip holding time[4] (s)	66.2±14.1	----	----	----	66.3±16.7
Loads carried[5] (kg)	----	----	----	----	32.5[illegible]

[1]Mean±standard deviation.
[2]Significantly different from baseline: †$p<0.10$; *$p<0.05$; **$p<0.01$.
[3]Significantly different from preceeding phase: a$p<0.10$; b$p<0.05$; c$p<0.01$.
[4]Grip holding time test performed immediately after maximal grip strength test, both as 60% of the first test.
[5]Weight carried at end of final course mission, excluding ammunition & water, determined from weight of soldier with complete load minus weight of clothed soldier without weapon, pack, & LCE.

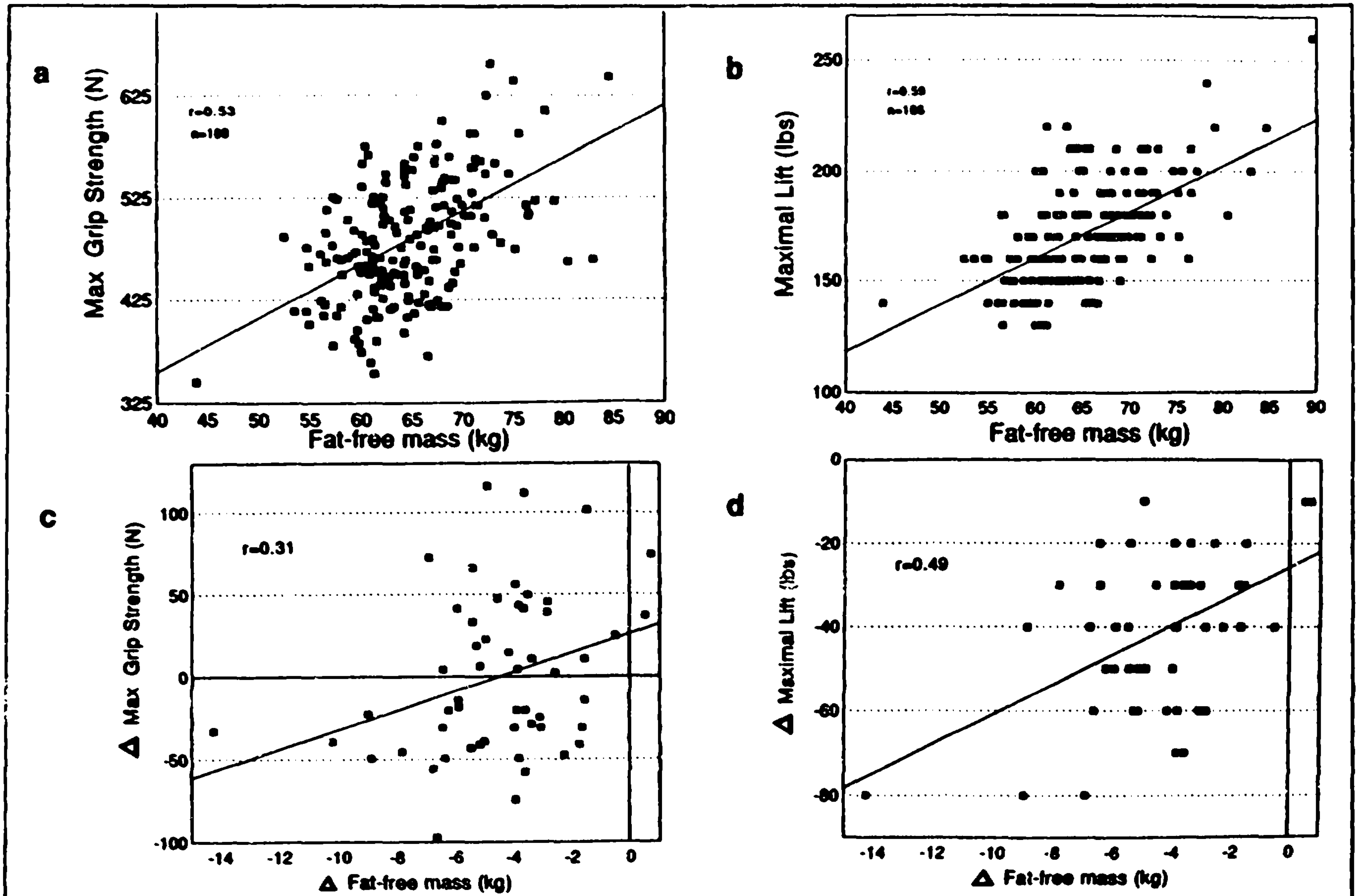


Figure 14. Relationships between FFM and grip strength (a) and maximal lift (b) at the start of the course (nonfinishers are included in these plots), and changes in grip strength (c) and maximal lift (d) through the course.

Individuals losing the least and the most FFM were compared for strength decrements and yielded the same relationships obtained by simple correlations (Table 14). There were no initial differences in physical characteristics of the soldiers at these two extremes (e.g. height, weight, body mass index) except for percent body composition measured by DEXA, with significantly higher FFM and lower percent body fat in the group which lost greater than 10% of their FFM during the course. This group demonstrated the greatest decrement in lift performance, with double the decrement compared to the group losing the least amount of FFM. There was no difference in the initial lift capacity of these two groups (72.6±10.9 vs 74.6±6.4 kg, for greatest and least loss of FFM, respectively).

Table 14. Comparison of physical changes during Ranger training for soldiers who lost >10% FFM (n=9) and < 4% FFM (n=9); soldiers in the mid-range of FFM loss (n=37) are shown for added comparison.

Parameter (change)	mid-range	>10% FFM	< 4% FFM	t-test
FFM loss (% initial)	6.9 ±1.6	12.6 ±3.0	1.8 ±1.7	< 0.01
Weight (kg)	-12.1 ±3.3	**-14.2 ±3.5**	**-9.7 ±2.3**	**< 0.01**
Sum of 4 skinfolds (mm)	-22.5 ±9.3	-19.3 ±6.9	-21.4 ±9.2	ns
Percent body fat_{DEXA}	-8.9 ±3.0	**-6.4 ±2.8**	**-10.7 ±3.4**	**< 0.05**
Percent body $fat_{skinfolds}$	-7.8 ±2.1	-7.9 ±1.6	-7.5 ±1.9	ns
Percent body fat_{Army}	-5.6 ±2.5	-6.5 ±2.0	-5.5 ±2.7	ns
FFM (kg)	-4.5 ±1.1	-8.5 ±2.6	-1.1 ±1.1	0.08
Bone mineral (kg)	-0.05 ±0.08	-0.06 ±0.07	-0.07 ±0.11	ns
Fat weight (kg)	-7.7 ±3.3	-5.7 ±2.7	-8.6 ±3.2	0.07
Grip strength max (N)	+1.6 ±52.4	-23.2 ±42.0	+13.6 ±55.9	ns
Grip hold endurance (s)	-0.9 ±19.6	+1.7 ±16.9	+3.0 ±9.8	ns
Maximal lift (kg)	-19.2 ±7.2	**-23.3 ±12.4**	**-12.5 ±5.8**	**< 0.05**

These data suggests that the maximal lift test is more affected by the loss of muscle mass than is the maximal grip strength. Handgrip strength probably has a large muscle fiber recruitment involvement while maximal lift strength is largely a function of the number of fibers (muscle cross-sectional area). Thus, caloric restriction in Ranger training, as in other studies, apparently does not affect neuromotor control but clearly does reduce muscle cross-sectional area.

ENERGY EXPENDITURE AND WATER TURNOVER

The pattern of total daily energy expenditure (TDEE) is shown in Figure 15. The TDEE estimated by DLW and intake balance (4010±830 kcal/day), and intake balance alone (3930±290 kcal/day), were similar. The highest TDEE was during the classroom portion of the Mountain phase when scheduled activities occupied approximately 19 hours/day; the second highest during the 4-day RAP period at the start of the course. The TDEE estimates for the final FTX of the Ft. Benning phase are less reliable than the initial measurements due to the high rate of water turnover

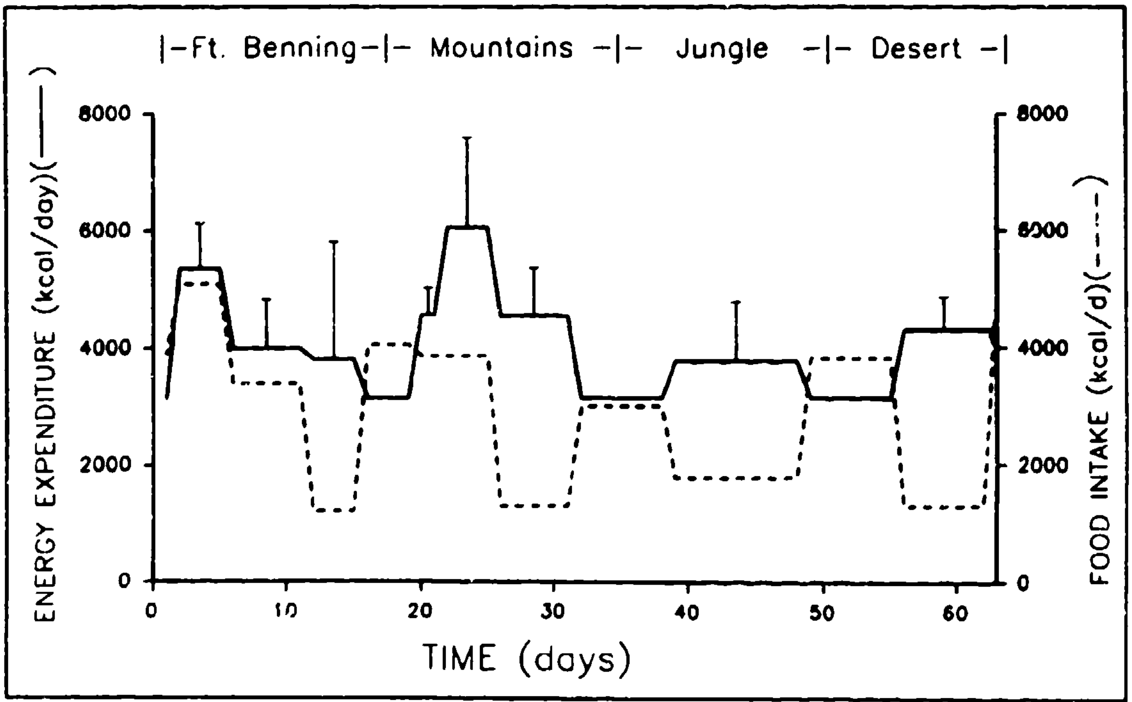


Figure 15. Total daily energy expenditure (solid line) and estimated food energy intake (dashed line) plotted over the course of Ranger training.

and the rapid elimination of the DLW. The TDEE during the three periods between DLW measurements was calculated as 3140 kcal/day.

In Figure 15, estimated food energy intake is plotted with TDEE. Energy balance, i.e., the net difference between food energy intake and energy expenditure, is shown in Figure 16. In the Ft. Benning phase, TDEE was the second highest of the four phases but food intake was relatively high. As a result, the Ft. Benning phase contributed the least of the four phases to the overall energy deficit (15%). In contrast, the Mountain phase, with the highest TDEE and a low food intake, contributed the most (37%) to the overall energy deficit. The transition from the Mountain to Jungle phases appeared to be a period of neutral energy balance. In the Jungle phase, the combination of prolonged, moderate TDEE and low food intake resulted in a negative energy balance totalling 33% of the total energy deficit. The Desert phase began with a period of refeeding and positive energy balance, moderating the overall energy deficit incurred after the food restriction and physical activity of the FTX (15% of total deficit). During structured periods of training in the Ft. Benning, Mountain, and Desert phases, 68% to 84% of the variation in TDEE could apparently be ascribed to differences in the fat free mass (FFM) of the soldiers. On

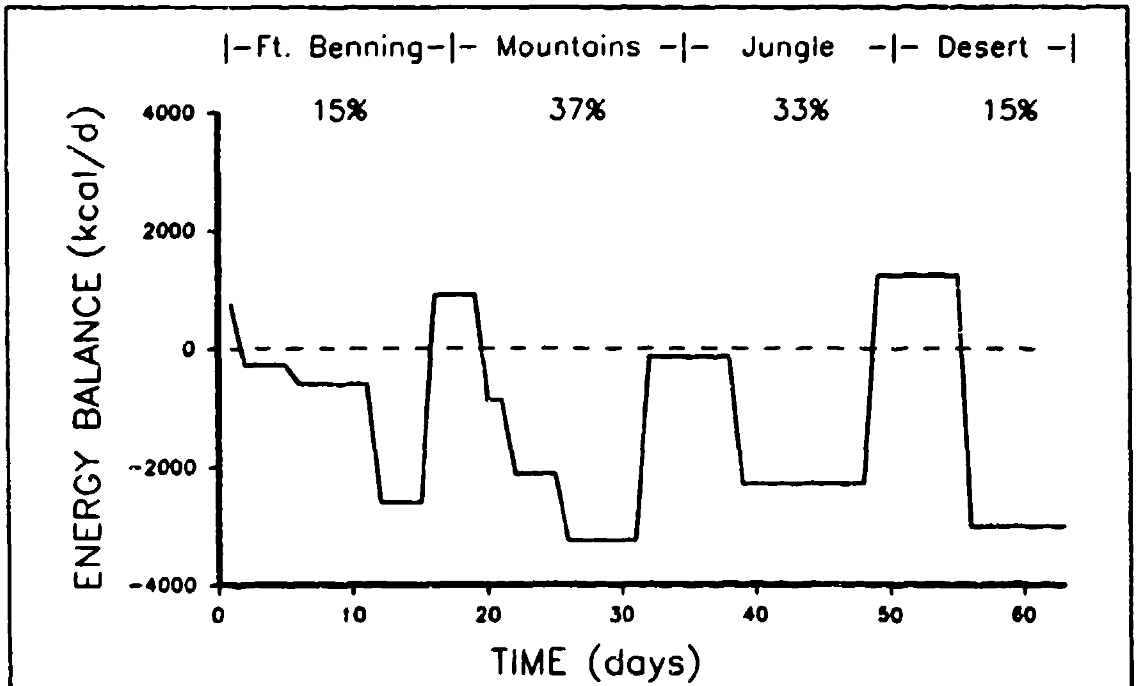


Figure 16. Energy balance during the course of Ranger training. This represents the next difference between food energy intake and energy expenditure.

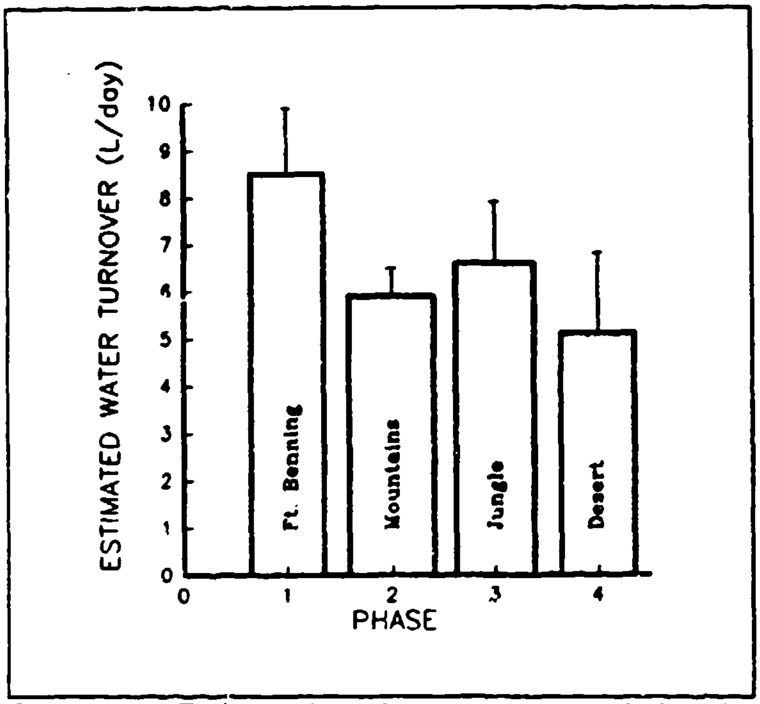


Figure 17. Estimated total water turnover during the four phases of the Ranger training course.

average, TDEE was 4010 kcal/day with about 1230 kcal/day or 31% from body energy stores, and 2780 kcal/day or 69% from food consumed.

Estimated total water turnover is shown in Figure 17. These estimates of water turnover include not only preformed drinking water consumed, but also metabolic water, water trapped in food, and water entering through the skin and lungs. These latter sources of water, which are approximately 10% of total water turnover or 0.5 to 1.0 liter/day, can be subtracted from the total water turnover to estimate preformed dietary water intake. Estimated preformed dietary water intake for each phase was: 7.4±1.2, (Ft. Benning), 5.3±0.6 (Mountain phase), 5.9±1.1 (Jungle phase), and 4.4±1.6 L/day, (Desert phase). These turnover rates demonstrate the emphasis by the cadre on high water intake, especially in the first phase during the greatest heat strain.

CLINICAL CHEMISTRIES

Serum iron concentrations declined to marginally deficient levels at the end of the first 2 weeks of training but then climbed back to the normal range (> 9.0 umol/L)(Table 15). Ferritin, a key protein involved in iron storage, increased in the serum over the course of the study, possibly as a compensatory mechanism to maintain normal iron levels.

Hemoglobin and hematocrit remained within normal limits throughout the course for all individuals as well as for group means (normal hemoglobin: >14 g/dL; normal range for hematocrit: 39-49%)(Figure 18). This was contrary to expectations because

of reports in the literature on "sports anemia" in athletes working at high intensities for prolonged periods of time.

Liver function tests and enzymic markers of muscle metabolism all remained within normal limits during the course (Table 16). Only serum levels of LDH (lactate dehydrogenase) demonstrated any meaningful rise and this remained within the normal range (140-280 U/L).

Serum mineral and electrolyte concentrations remained unchanged throughout the course (Table 17). This indicated that there was no detectable electrolyte deficiency at the times where this would be most likely, when the soldiers had just completed the intensive field portion of the phase, on a schedule of one MRE/day.

Serum indices of energy and nitrogen metabolism may reflect the changes in metabolism which occur in response to storage fat depletion, beginning midway through the course (Table 18). Serum glycerol, nonesterified fatty acids, and β-hydroxybutyrate increased at the end of the first and second phases and then declined, while urea nitrogen increased to the highest mean levels at the end of the

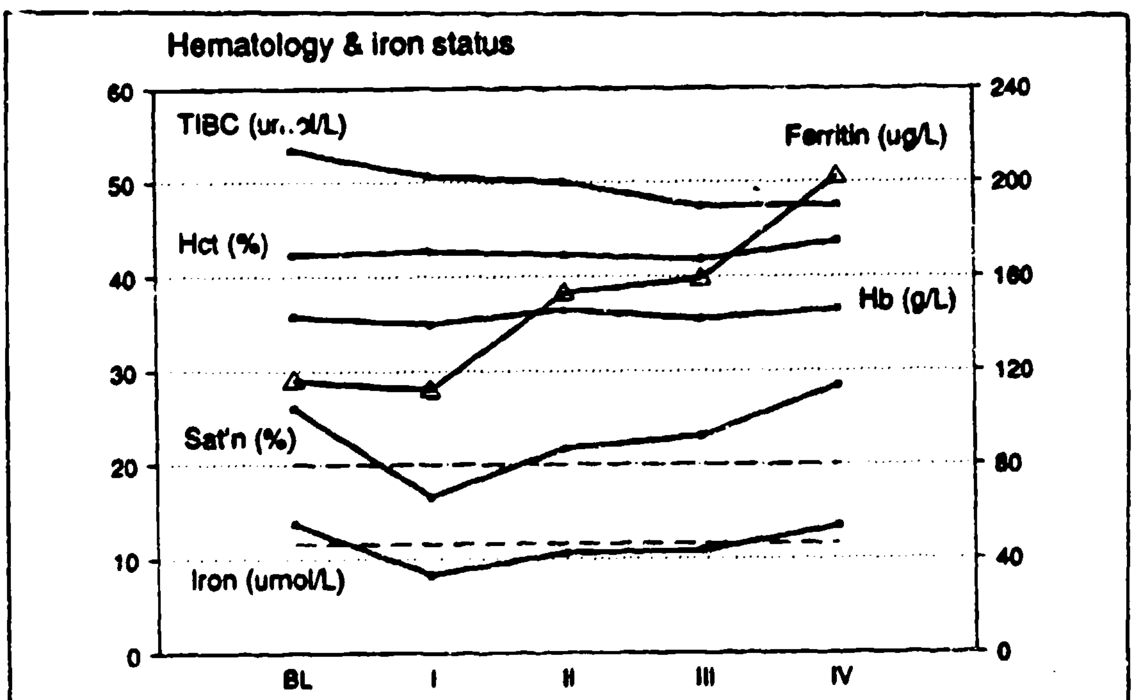


Figure 18. Iron balance and related hematological parameters during Ranger training.

Table 15. Serum Iron and Ferritin Levels, Total Iron-binding Capacity, % Iron Saturation, Red Blood Cell Count, Hemoglobin and Hematocrit of Soldiers During the Ranger Training Course[1,2,3]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	51	48	48	45	49
Iron, μmol/L	13.7 ± 5.6	$8.3 \pm 3.6^{**}$	$10.6 \pm 4.2^{**c}$	$10.8 \pm 3.5^{**}$	13.4 ± 5.5^{c}
TIBC, μmol/L	53.4 ± 6.8	$50.6 \pm 6.7^{**}$	$50.0 \pm 6.0^{**}$	$47.4 \pm 5.6^{**c}$	$47.5 \pm 6.3^{**}$
Transferrin Saturation, %	26.0 ± 11.0	$16.6 \pm 7.5^{**}$	$21.7 \pm 9.4^{\dagger c}$	$23.0 \pm 8.4^{\dagger}$	28.4 ± 11.3^{c}
Ferritin, μg/ml	116 ± 84	112 ± 53	153 ± 82	159 ± 89	202 ± 106
RBC, $\times 10^3$/μL	4.71 ± 0.27	4.62 ± 0.35	4.78 ± 0.29	4.64 ± 0.26	4.76 ± 0.38
Hb, g/L	143 ± 8	140 ± 8	146 ± 9	142 ± 7	146 ± 8
Hct, %	42.3 ± 2.2	42.7 ± 2.9	42.3 ± 2.3	41.8 ± 1.9	43.7 ± 2.9

[1]Mean±standard deviation.
[2]Significantly different from baseline: $^{\dagger}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3]Significantly different from preceeding phase: $^{a}p<0.10$; $^{b}p<0.05$; $^{c}p<0.01$.

Table 16. Serum Enzymic Markers of Hepatobiliary and Muscle Metabolism of Soldiers During the Ranger Training Course[1,2,3]

	Training Phase				
Item[4]	Baseline	Benning	Mountain	Jungle	Desert
n^5	51(50)	48(48)	48(49)	45(46)	49(50)
LDH, U/L	168 ± 51	$243 \pm 48^{**}$	$243 \pm 58^{**}$	$226 \pm 44^{**c}$	$224 \pm 48^{**}$
GGT, U/L	16.2 ± 5.0	13.5 ± 4.6	14.2 ± 4.5	13.9 ± 4.4	15.8 ± 6.2
ASAT, U/L	44 ± 31	44 ± 16	$55 \pm 26^{*c}$	50 ± 17^{b}	47 ± 18
ALAT, U/L	22 ± 10	$32 \pm 12^{**}$	$33 \pm 14^{**}$	$28 \pm 13^{**c}$	$32 \pm 12^{**c}$
Bilirubin, µmol/L	20.6 ± 13.8	$17.1 \pm 8.6^{*}$	22.5 ± 10.4^{c}	$17.3 \pm 5.8^{\dagger c}$	21.2 ± 8.0^{c}

[1] Mean±standard deviation.
[2] Significantly different from baseline: $^{\dagger}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3] Significantly different from preceeding phase: $^{a}p<0.10$; $^{b}p<0.05$; $^{c}p<0.01$.
[4] LDH=lactate dehydrogenase, GGT= γ-glutamyl transaminase, ALAT=alanine aminotransferase, ASAT=aspartate aminotransferase.
[5] (n) number of observations for ASAT and ALAT.

Table 17. Serum Mineral and Electrolyte Concentrations in Soldiers During the Ranger Training Course[1]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	51	48	48	45	49
Ca, mmol/L	2.48±0.08	2.49±0.09	2.56±0.08	2.51±0.07	2.56±0.09
P, mmol/L	1.42±0.28	1.43±0.14	1.51±0.17	1.38±0.15	1.38±0.16
Mg, mmol/L	0.91±0.06	1.00±0.07	0.93±0.09	1.02±0.07	1.03±0.05
Na, mmol/L	139±2	141±2	137±3	138±2	138±2
K, mmol/L	4.2±0.3	4.1±0.3	4.2±0.4	4.0±0.4	4.1±0.3
Cl, mmol/L	103±3	104±2	100±3	101±2	102±2

[1]Mean±standard deviation.

Table 18. Serum Indices of Energy and Nitrogen Metabolism in Soldiers During the Ranger Training Course[1,2,3]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n^4	51(50)	48(48)	48(49)	45(46)	49(50)
Glucose, mmol/L	4.8±0.4	4.3±0.4**	3.8±0.6**c	4.2±0.7**c	3.9±0.5†c
Lactate, mmol/L	1.9±0.6	3.4±1.5**	3.1±1.9**	3.3±2.4**	2.2±0.8*c
Urea N, mmol/L	6.2±1.4	6.0±1.2	7.2±1.6**c	7.7±2.0**	7.0±1.7**b
Uric acid, mmol/L	369±90	356±52	362±60	356±59	348±57*
Creatinine, µmol/L	103±14	112±14	104±11	113±13	109±10
Total protein, g/L	71±7	73±4	75±4	73±4	75±5
Albumin, g/L	47±3	48±3	50±3	47±3	48±4
Glycerol, mmol/L	0.10±0.07	0.14±0.04**	0.21±0.08**c	0.16±0.07**c	0.16±0.05**
Nonesterified fatty acids, mmol/L	0.52±0.52	0.88±0.30**	1.35±0.41**c	0.74±0.48**c	0.98±0.39**c
β-hydroxybutyrate, µmol/L	320±470	710±860*	1200±620**c	350±220c	530±270*c

[1]Mean±standard deviation.
[2]Significantly different from baseline: †p<0.10; *p<0.05; **p<0.01.
[3]Significantly different from preceeding phase: [a]p<0.10; [b]p<0.05; [c]p<0.01.
[4](n) number of observations for glycerol, lactate, and nonesterified fatty acids.

third p: ase. Although these are acute markers which would change rapidly with a meal or with exercise, these changes could reflect increased protein catabolism when fat stores had been largely depleted, or they could simply mean that an adaptation to fat metabolism had occurred, bringing mobilization and oxidation into closer regulation. Nitrogen balance was not measured in this study but was presumably negative during periods of greatest energy deprivation; this is supported by the changes in endocrine nutritional markers such as IGF-1, described in the following section. There was no significant change in total protein or in serum albumin concentrations which also suggests the absence of chronic protein malnutrition.

Serum cholesterol demonstrated a progressive rise through Ranger training, with representative rises in both of the principal subfractions, but without any increase in triglyceride levels (Figure 19, Table 19). These serum lipid changes are consistent with two other processes occuring during semistarvation: a diabetic-like state (with extremely low insulin levels and peripheral insulin resistance) and hypothyroidism (discussed further in a section below on endocrine changes). Both of these conditions are well established underlying causes of hypercholesterolemia. Psychological stress produces a marked suppression of the HDL-cholesterol subfraction, a response quite different from these observations in Ranger students.

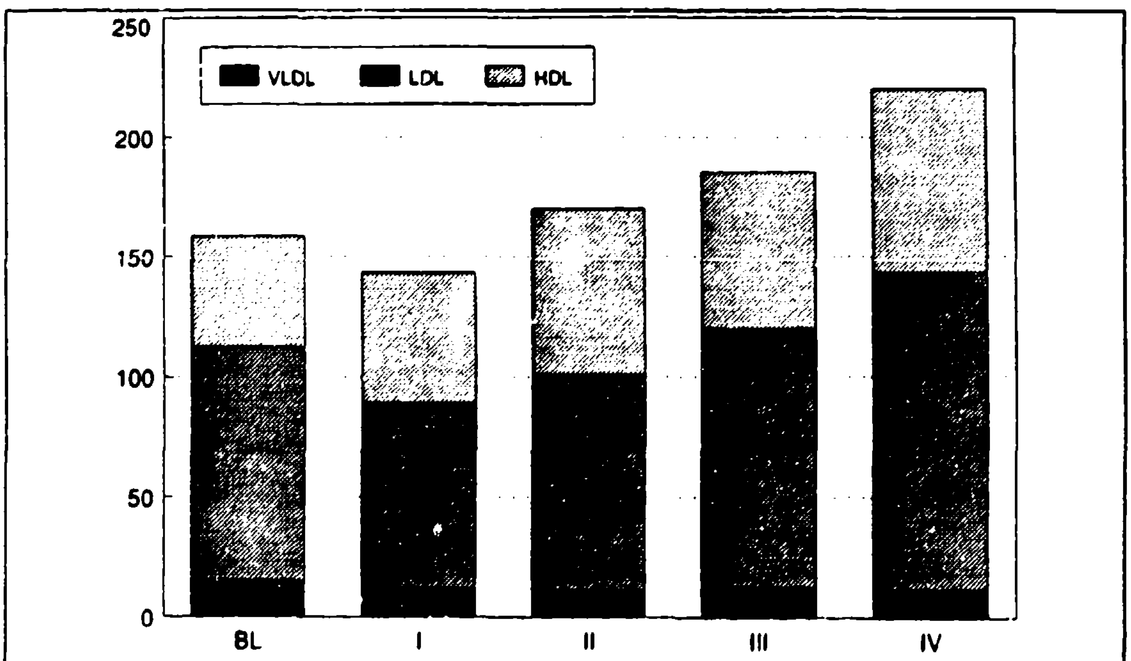


Figure 19. Serum cholesterol subfraction levels at the beginning and end of each phase of training (note the use of traditional mass units, mg/dL).

Table 19. Serum Cholesterol and Triglyceride Levels in Soldiers During the Ranger Training Course[1,2,3]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n[4]	51(50)	48(48)	48(49)	45(46)	49(50)
Cholesterol, mmol/L	4.1 ± 0.8	$3.7 \pm 0.8^{**}$	$4.4 \pm 0.9^{*c}$	$4.8 \pm 0.9^{**c}$	$5.7 \pm 1.0^{**c}$
Triglyceride, mmol/L	0.87 ± 0.27	0.68 ± 0.11	0.63 ± 0.09	0.72 ± 0.12	0.68 ± 0.10
HDL-Cholesterol, mmol/L	1.2 ± 0.2	$1.4 \pm 0.2^{**}$	$1.8 \pm 0.3^{**c}$	$1.7 \pm 0.3^{**c}$	$2.0 \pm 0.4^{**c}$
LDL-Cholesterol, mmol/L	2.4 ± 0.7	$2.0 \pm 0.7^{**}$	2.3 ± 0.8	$2.8 \pm 0.8^{**c}$	$3.4 \pm 0.9^{**c}$

[1]Mean$\pm$standard deviation.
[2]Significantly different from baseline: $^{\dagger}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3]Significantly different from preceeding phase: $^{a}p<0.10$; $^{b}p<0.05$; $^{c}p<0.01$.
[4](n) number of observations for HDL-cholesterol.

VITAMIN STATUS

Serum vitamin concentrations <u>increased</u> over time in the course for several vitamins, with a significant decrement in the middle of the course only for Vitamin A (Table 21). The absence of a change, or even a decline, in erythrocyte-stimulated enzyme activities indicates that no deficiency evolved for thiamin, riboflavin, and B_6.

Soldiers who used no vitamin supplements during the course had lower but still normal results (Figures 20 & 21), with statistically lower mean concentrations for serum B_{12} and 25-OH-D_3, serum and erythrocyte folate, and higher levels of enzyme markers of B_6 and riboflavin (Table 22). The decline in Vitamin A with an apparent recovery even following the stressful third phase in the jungle environment cannot be explained. The actual <u>increase</u> in some indicators of vitamin status suggests that using the nutrient fortified MRE (Table 20) and intervals of increased feeding, there is no critical nutrient deficiency. No differences in serum nutrient levels were found between soldiers at the extremes of fat-free mass change, compared as in Table 14.

Table 20. Estimated average daily nutrient intake over the entire course & during FTX days when soldiers received only a single MRE per day.

	MRDA[1]	Average Intake/day[2]	% MRDA	FTX Intake/day	% MRDA
Energy, kcal	3200	2524	**79**	1306	**41**
Vitamin A, IU	5000	9905	**198**	4213	**84**
Vitamin C, mg	60	171	**285**	105	**175**
Thiamin (B_1), mg	1.6	3.6	**225**	2.7	**169**
Riboflavin (B_2), mg	1.9	1.8	**95**	1.1	**58**
Niacin, mg	21	21	**100**	13	**62**
Vitamin B_6, mg	2.2	1.8	**81**	1.9	**86**
Folacin, mcg	400	-	-	73	**18**
Calcium, mg	800-1200	1172	**117**	501	**50**
Iron, mg	10-18	13	**93**	6	**43**

[1]MRDA = Military Recommended Dietary Allowances for moderately active Army personnel (AR 40-25)(12).
[2]Average daily food intake predicted from data in the Ranger Operational Feeding Plan and known nutrient composition of military foods.

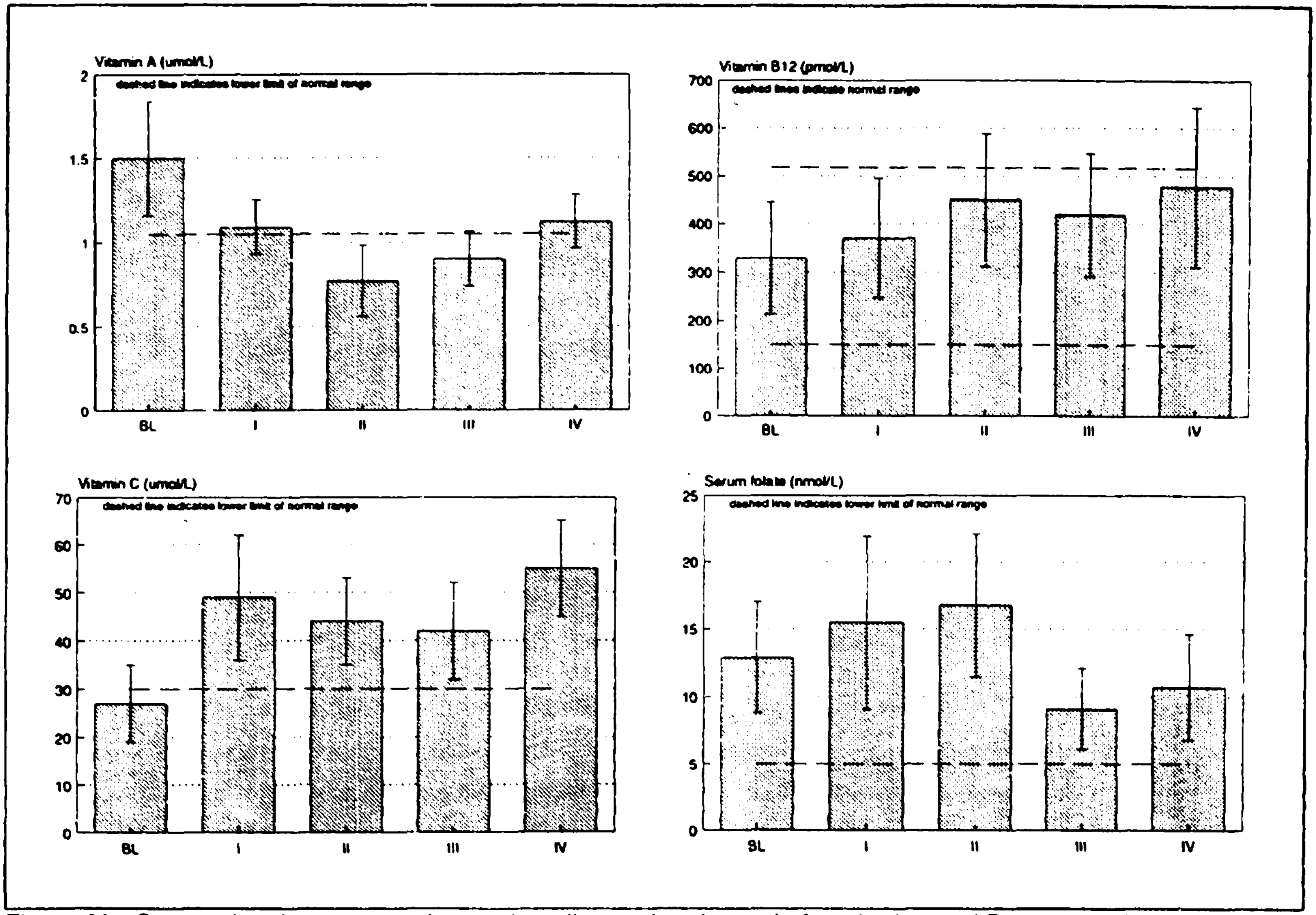


Figure 20. Serum vitamin concentrations at baseline and at the end of each phase of Ranger training (data shown for soldiers who used no vitamin supplements during Ranger training, n=20).

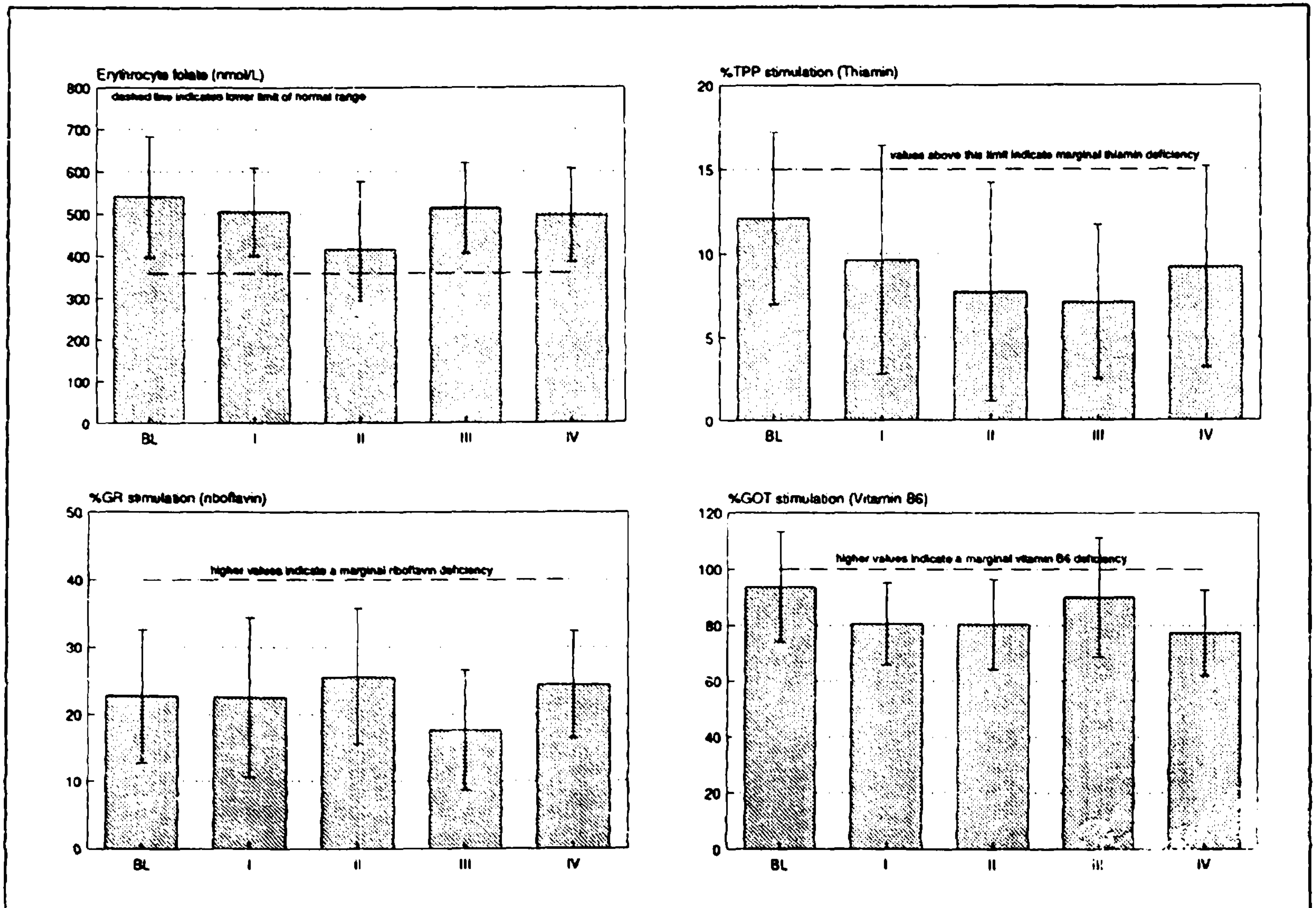


Figure 21. Erythrocyte folate concentrations and erythrocyte enzyme stimulation tests at baseline and at the end of each phase of Ranger training (data shown for soldiers who used no vitamin supplements).

Table 21. Indices of Vitamin A, C, D, B_{12}, B_6, Folate, Thiamin, and Riboflavin Status in Serum and Erythrocytes of Soldiers during the Ranger Training Course[1,2,3]

Item[4]	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	48	47	48	44	48
Serum					
Vitamin A, µmol/L	1.37±0.34	1.02±0.19**	0.76±0.20^{**c}	0.92±0.18^{**c}	1.09±0.21^{**c}
Vitamin B_{12}, pmol/L	389±149	455±202^{**c}	601±263^{**c}	532±258^{**a}	579±290**
Folate, nmol/L	17.6±8.4	16.8±6.6	20.2±7.6^{*c}	13.3±7.3^{**c}	15.6±7.5^{a}
Vitamin C, µmol/L	32±16	48±13^{**c}	45±11**	43±11**	56±11^{**c}
Vitamin 25-OH-D_3, nmol/L	97±24	93±2^{‡a}	109±37^{**c}	121±30^{**a}	115±26**
Erythrocyte					
TK, % stimulation	12.8±8.2	8.8±5.7^{**c}	7.2±6.1**	8.5±5.0**	9.1±6.4**
GR, % stimulation	19.7±10.5	20.9±10.0	22.1±9.8‡	15.4±7.8^{*c}	21.3±9.1^{c}
GOT, % stimulation	90.7±18.8	76.1±16.5^{**c}	75.6±16.7**	84.6±19.9^{‡c}	75.4±15.6^{**c}
Folate, nmol/L	614±186	576±179	495±184^{**c}	570±187^{b}	590±190

[1]Mean±standard deviation.
[2]Significantly different from baseline: $^{†}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3]Significantly different from preceeding phase: $^{a}p<0.10$; $^{b}p<0.05$; $^{c}p<0.01$.
[4]25-OH-D_3=25-hydroxycholecalciferol, TK=transketolase (marker of thiamin status), GR=glutathione reductase (marker of riboflavin status), GOT=glutamate-oxaloacetate transaminase (marker of Vitamin B_6 status).

Table 22. Indices of Vitamin A, C, D, B_{12}, B_6, Folate, Thiamin, and Riboflavin Status in Serum and Erythrocytes of Soldiers who used no Supplements during the Ranger Training Course[1,2,3]

	Training Phase				
Item[4]	Baseline	Benning	Mountain	Jungle	Desert
n	20	21	18	19	22
Serum					
Vitamin A, μmol/L	1.50±0.34	1.09±0.16[**c]	0.77±0.21[**c]	0.90±0.16[**b]	1.12±0.16[**c]
Vitamin B_{12}, pmol/L	328±116	370±124[*]	450±138[**]	419±128[**]	478±166[**]
Folate, nmol/L	12.9±4.1	15.5±6.4[*b]	16.8±5.3[**]	9.1±3.0[**c]	10.7±3.9[†]
Vitamin C, μmol/L	27±8	49±13[*b]	44±9[**]	42±10[**]	55±10[**a]
Vitamin 25-OH-D_3, nmol/L	89±16	87±23	103±33[*b]	110±28[**]	108±18[**]
Erythrocyte					
TK, % stimulation	12.1±5.1	9.6±6.8	7.7±6.5[*]	7.1±4.6[**]	9.2±6.0[*a]
GR, % stimulation	22.7±9.9	22.5±11.9	25.6±10.1[*]	17.6±9.0[c]	24.4±8.0[b]
GOT, % stimulation	93.6±19.5	80.5±14.6[**]	80.4±15.9[**]	90.0±21.2[b]	77.3±15.2[**b]
Folate, nmol/L	540±143	505±104	416±160[**c]	513±107[c]	496±110[*c]

[1]Mean±standard deviation.
[2]Significantly different from baseline: [†]$p<.10$; [*]$p<.05$; [**]$p<.01$.
[3]Significantly different from preceeding phase: [a]$p<.10$; [b]$p<.05$; [c]$p<.01$.
[4]25-OH-D_3=25-hydroxycholecalciferol, TK=transketolase, GR=glutathione reductase, GOT=glutamate-oxaloacetate transaminase.

ENDOCRINE RESPONSES

Generalized stress markers changed significantly to indicate a progressive stress response through the course (Table 23). Testosterone, the principal male sex steroid hormone is also one of the most sensitive and reliable stress hormone markers and this approached castrate levels by midcourse (Figure 22). Sex hormone binding protein (SHBG) doubled at the end of the first phase and remained elevated throughout the course with mean leveis just above the upper limit of the normal male range. This is an expected part of the stress response, equivalent to the changes which occur in the much shorter but more intense (no sleep and no food) Norwegian Ranger training course (14,15). This increase may be most directly attributable to the decline in insulin levels because insulin is a key inhibitor of SHBG secretion. The functional consequence of this rise is that the small amount of testosterone which remains in circulation is more likely to be protein bound, resulting in even lower circulating "free" testosterone, thought to be the biologically active fraction for some tissues. The decline in testosterone is explained by the observed 50% reduction in the pituitary hormone LH. LH is the primary trophic factor for testosterone production by the testes and is, in turn, regulated by hypothalamic hormones indicating that this is a centrally mediated stress response rather than a primary hypogonadism.

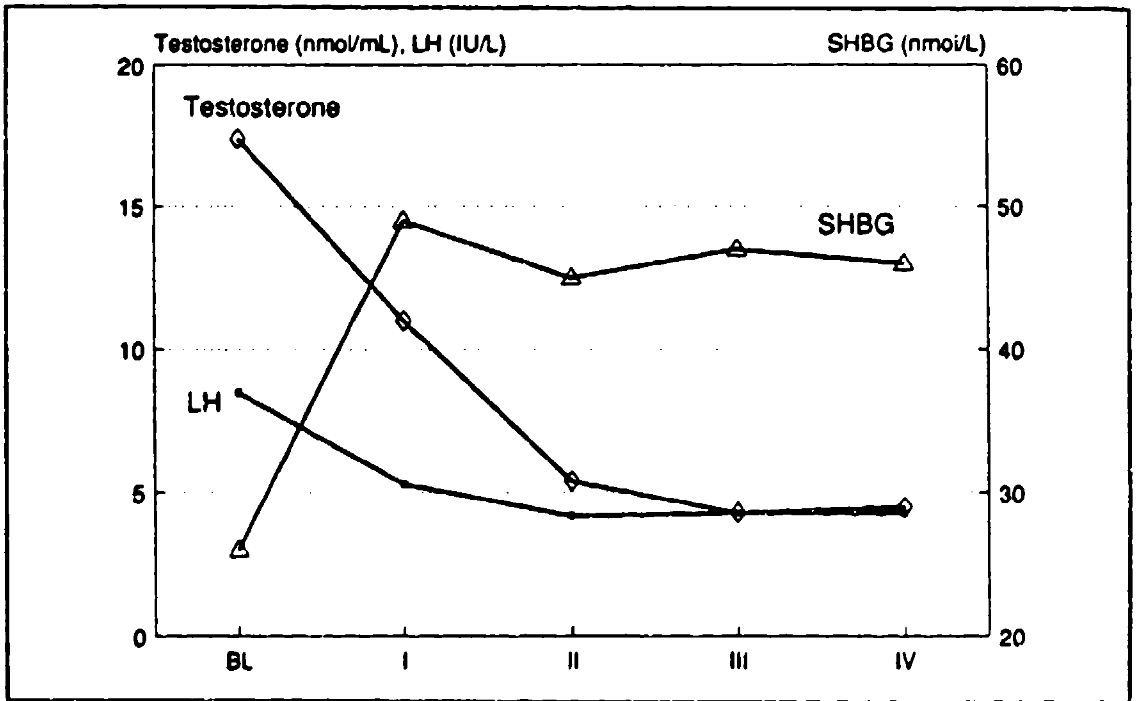


Figure 22. Declining serum testosterone and LH levels are indicators of a generalized stress response; increasing SHBG levels reflect the caloric deficit.

Adrenal steroids are better markers of short term stress and tend to return to baseline levels in chronic stress. However, in this study with progressive semi-starvation, cortisol was highest at the end of the course, signifying the normal response to a severe nutritional stress in the role of a metabolic hormone responsible for mobilizing protein stores for energy and increasing circulating free fatty acids (Table 23).

Serum insulin levels declined by 50% within the first phase and remained at these low levels at each end of phase sampling. Insulin-like growth factor-1 (IGF-1) declined to an even greater extent (Figure 23). This is one of the single best markers of nitrogen or protein balance, with this fall indicating the severity of the energy deficient diet and the catabolism of protein from body stores. Growth hormone demonstrated a normal semi-starvation response with a large rise from baseline. The large standard deviation in the final sample represents large growth hormone pulses captured at the time of blood sampling in six of the ten individuals with the largest FFM losses (Table 23). Serum triiodothyronine (T3) levels declined by 40%, consistent with the normal response in semistarvation to reduce metabolic rate. This reduction is also important during infection. The more potent thyroid hormone, thyroxine (T4), also declined but to a smaller extent (data not shown).

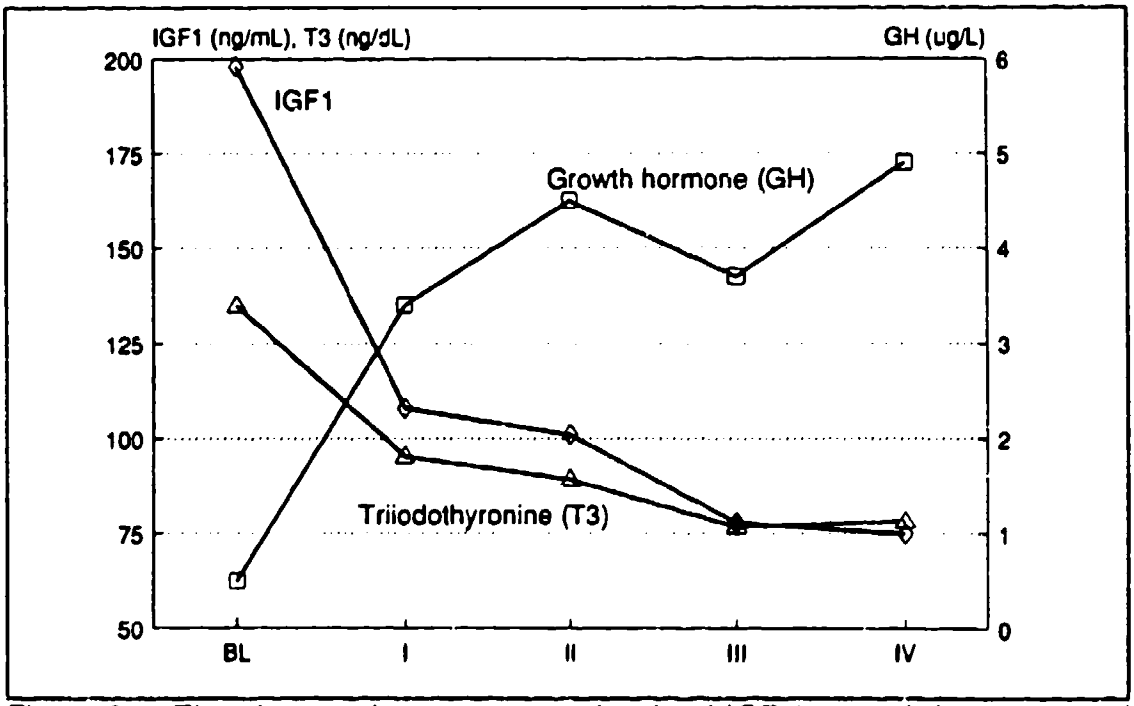


Figure 23. The changes in mean serum levels of IGF-1, growth hormone, and triiodothyronine reflect normal responses to a prolonged energy deficit.

Table 23. Stress Hormone Levels in Soldiers During the Ranger Training Course[1-3]

Item	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n^4	49	49	49	49	49
Testosterone, mmol/L	17.4 ± 5.9	$11.0 \pm 5.2^{**c}$	$5.4 \pm 3.7^{**c}$	$4.3 \pm 3.6^{**b}$	$4.5 \pm 3.5^{**}$
Estradiol-17β, pmol/L	52 ± 14	$35 \pm 11^{**c}$	$40 \pm 12^{**c}$	$34 \pm 12^{**c}$	$39 \pm 10^{**c}$
SHBG, nmol/L	26 ± 10	$49 \pm 19^{**c}$	$45 \pm 17^{**b}$	$47 \pm 19^{**a}$	$46 \pm 16^{**}$
Luteinizing hormone, IU/L	8.5 ± 3.1	$5.3 \pm 2.8^{**c}$	$4.2 \pm 2.1^{**c}$	$4.3 \pm 2.8^{**}$	$4.3 \pm 2.2^{**}$
Cortisol, mmol/L	468 ± 117	458 ± 83	$582 \pm 126^{**c}$	$528 \pm 100^{**c}$	$646 \pm 119^{**c}$
Aldosterone, ng/dL[4]	16 ± 12	20 ± 12	35 ± 27	21 ± 9	----
Insulin, μIU/ml[4]	4.9 ± 2.4	2.5 ± 1.3	2.4 ± 1.3	2.9 ± 1.4	3.0 ± 1.5
IGF-1, ng/ml	198 ± 54	$108 \pm 33^{**c}$	$101 \pm 32^{**a}$	$78 \pm 24^{**c}$	$75 \pm 25^{**}$
Growth hormone, μg/L	0.5 ± 0.7	$3.4 \pm 3.0^{**c}$	$4.5 \pm 3.5^{**}$	$3.7 \pm 3.1^{**a}$	$4.9 \pm 7.2^{**}$
Triiodothyronine, ng/dL[4]	135 ± 21	95 ± 22	89 ± 22	77 ± 17	78 ± 19

[1]Mean±standard deviation.
[2]Significantly different from baseline: $^{\dagger}p<0.10$; $^{*}p<0.05$; $^{**}p<0.01$.
[3]Significantly different from preceeding phase: $^{a}p<0.10$; $^{b}p<0.05$; $^{c}p<0.01$.
[4]Statistical comparisons not performed.

DELAYED SKIN HYPERSENSITIVITY TEST

Delayed-type-hypersensitivity (DTH) skin-test reaction is an *in vivo* test for immune competence and function of T-lymphocytes and macrophages. A positive DTH response confirms previous exposure of the individual to the test antigen. The exposure can be environmental contamination and or prophylactic immunization. DTH skin-test responsiveness of the Ranger students at baseline and upon completion of the jungle and desert phases to antigens of 7 microorganisms is presented in Table 24. Compared to baseline, the percent number of trainees showing positive DTH skin-test responses to the test antigens tetanus, candida, streptococcus, and tricophyton did not change during the course. Increases were found in the percent number of trainees showing positive DTH skin-test responses to test antigens diphtheria, at the end of the jungle phase, proteus, at the end of both the jungle and desert phases, and tuberculin, at the end of the desert phase. These results demonstrate that T-lymphocyte function in the DTH skin-test reaction is maintained by trainees during the Ranger course. In summary, Ranger training does not impair the ability of the trainee to express cellular immunity to infectious microorganisms that they had developed immunity to prior to the start of training.

Antigen	Baseline	Jungle	Desert
Tetanus	91	87	85
Diphtheria	56[a]	74[b]	65[a,b]
Candida	56	56	56
Proteus	47[a]	65[b]	69[b]
Streptococcus	24	18	25
Tuberculin	16[a]	16[a]	31[b]
Tricophyton	15	24	15

Percent positive skin-test sites; Inducation $\geq$ 2 mm in diameter. Values for each antigen marked with unsimilar letters are different $(p<0.05)$.

Table 24. Delayed-type-hypersensitivity skin test responsiveness at baseline and at the end of jungle and desert phases.

CELL-MEDIATED IMMUNE FUNCTION

T-lymphocytes are the immune specific cells involved in the DTH reaction. Since it is difficult to evaluate T-lymphocytes individually in the complex in vivo DTH reaction, in vitro tests have been developed to evaluate the function of these cells. T-lymphocytes cultured in vitro undergo proliferation when stimulated with certain lectins, such as pokeweed mitogen (PWM), phytchemagglutinin (PHA) or concanavalin-A (ConA), or antigens, such as tetanus toxoid (TT), to which the individual has been immunized.

Proliferative activity in vitro of lymphocytes from trainees at baseline, and upon completion of Benning, mountain, jungle and desert phases stimulated with PWM, PHA, Con A, or TT are shown in Figure 24. Compared to baseline, proliferative responsiveness in vitro of T- and B-lymphocytes to PWM was significantly decreased in the trainees upon completion of the Benning phase, followed by additional and equivalent reduction upon completion of the mountain and jungle phases. A partial recovery, equivalent to Benning phase levels, was observed at the end of the desert phase. Similar results were observed for T-lymphocytes stimulated with PHA-M, which primarily stimulates T-lymphocytes. With minor exceptions, proliferative responsiveness of T-lymphocytes from the trainees to Con A (a T-lymphocyte mitogen) was similar to those for T-lymphocytes stimulated with PWM or PHA-M. Regardless of the mitogenic stimulant, T-lymphocyte proliferation was reduced most in the trainees upon completion of the mountain and jungle phases. Also, T-lymphocyte proliferation was partially (PWM, PHA-M) or fully recovered (ConA) upon completion of the desert phase. Proliferation of T-lymphocytes to the antigen TT was suppressed in trainees at the end of the mountain phase, but recovered at the end of the jungle and desert phases.

The cytokine interleukin-2 (IL-2) is synthesized and secreted primarily by T-helper lymphocytes which have been stimulated with certain mitogens or antigens. Binding of IL-2 to receptors for IL-2 (IL-2R) induces clonal expansion of antigen-specific T-lymphocytes involved in immune protection against infectious diseases. Release of soluble IL-2R and the production of IL-2 by T-lymphocytes stimulated with PHA-M from the trainees at baseline, and upon completion of Benning, mountain, jungle and desert phases are presented in Figure 25a and 25b. Compared to baseline, IL-2R and IL-2 were significantly decreased by T-lymphocytes from trainees upon completion of the Benning and mountain phases. IL-2R and IL-2 were fully

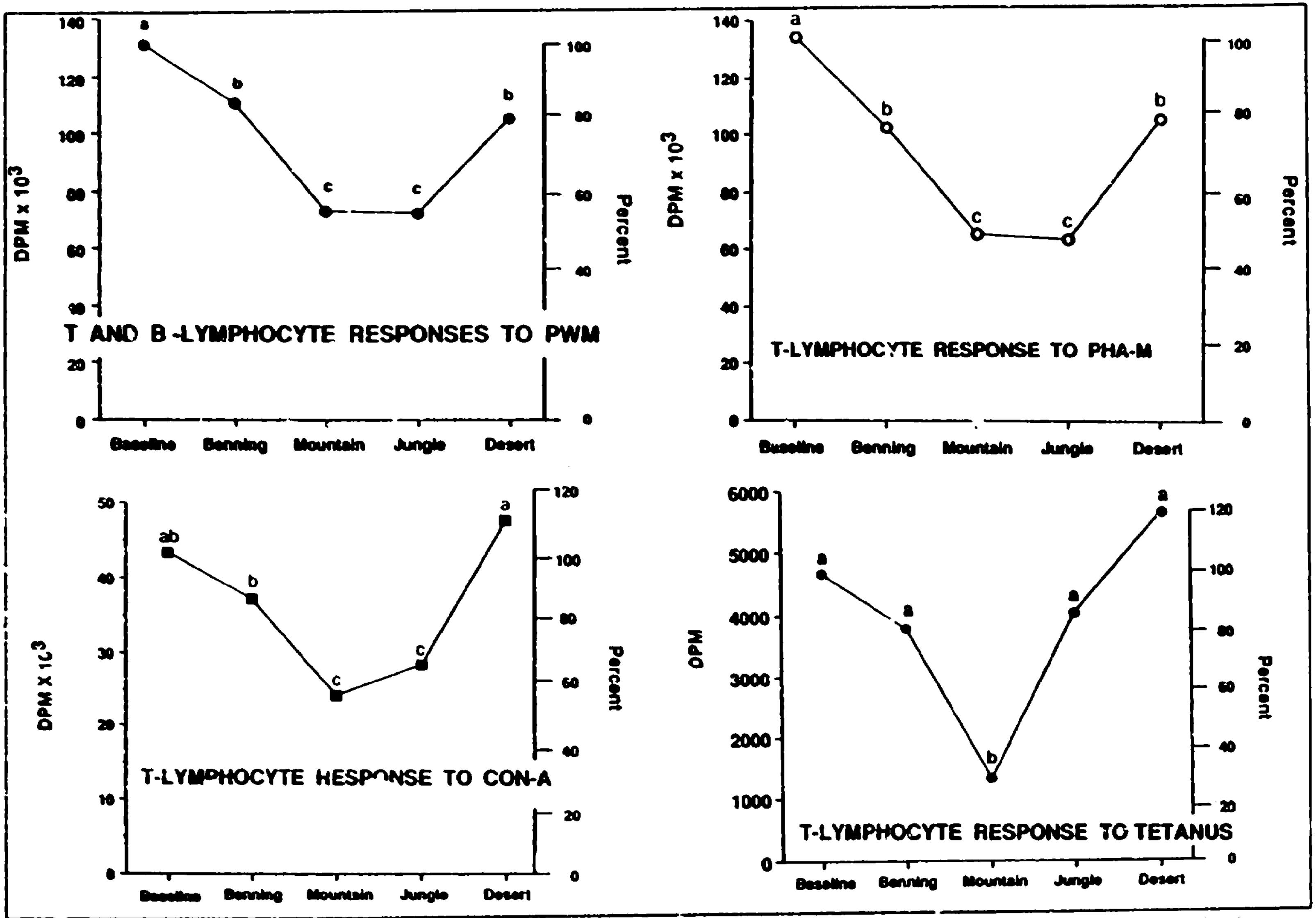


Figure 24. Proliferative activity of lymphocytes collected through the course and stimulated with pokeweed mitogen, phytohemagglutinin, concanavalin A, or tetatus toxoid in vitro. Values with dissimilar letters are different at $p<0.05$.

recovered to baseline level at the end of the jungle phase, and IL-2 was significantly increased above baseline upon completion of the desert phase. Similar to IL-2R and IL-2, proliferation of T-lymphocytes stimulated with PHA (Figure 25c) shows suppressed T-lymphocyte function by the Ranger trainees during the course. The suppressed T-lyphocyte functions in vitro appear to be primarily due to energy deficit. It also appears that early responses (IL-2R and IL-2) of T-lymphocyte activation/function normalize quicker to improved energy status than the late response, i.e. proliferation/DNA-synthesis.

The cytokine interleukin-6 (IL-6) is a multifunctional protein produced by lymphoid and non-lymphoid cells. The primary sources of IL-6 from unstimulated whole-blood cultures would be T-helper lymphocytes and monocytes/macrophages. These cells plus fibroblasts, hepatocytes, and vascular endothelial cells would be the primary sources of IL-6 in plasma. Although IL-6 is a multifunctional cytokine it has a major role in the mediation of the inflammatory and immune responses initiated by infection or injury. Production of IL-6 by unstimulated whole-blood cultures from trainees at baseline, and upon completion of the Benning, mountain, jungle and desert phases are presented in Figure 26. Compared to baseline, whole-blood produced IL-6 was significantly decreased in the trainees upon completion of the jungle phase. Concentrations of IL-6 in cell culture supernatants were lower in trainees upon completion of the Benning, mountain and desert phases than at baseline, but not significantly.

Levels of IL-6 in plasma of trainees at baseline, and upon completion of the Benning, mountain, jungle and desert phases are shown in Figure 26. Compared to baseline, plasma IL-6 concentration was significantly increased at the end of the Benning phase, followed by significant decreases at the end of the jungle and desert phases. From the Benning through desert phase the trainees showed continued decreases in plasma IL-6 at each phase.

In summary, Ranger training had a suppressive effect on cellular functions of the immune protective system. The suppression was greatest at the time of highest energy expenditure and largest energy deficit (end of mountain phase). This preceeded the periods of increased incidences of infections (jungle and desert phases) in the trainees.

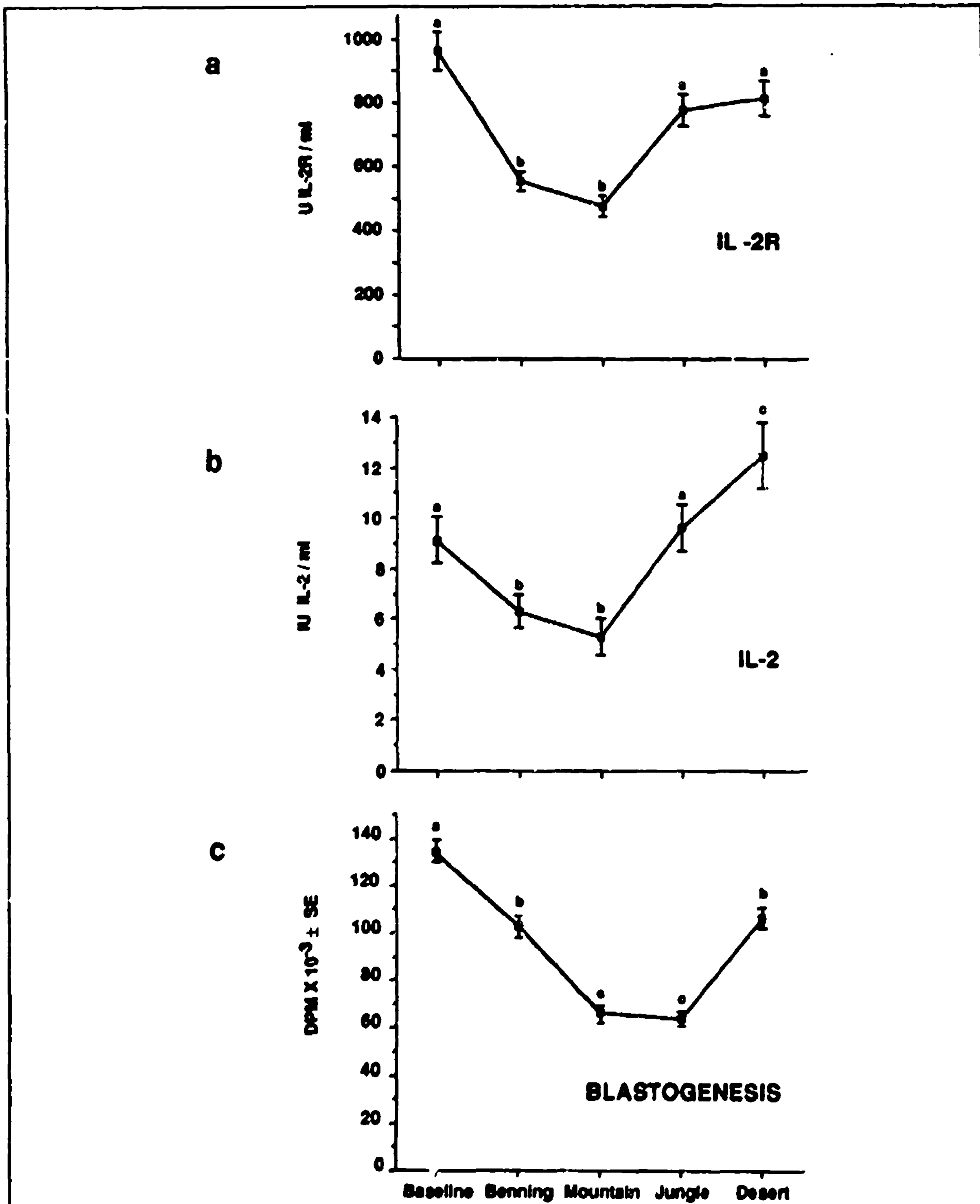


Figure 25. Changes and recovery of 3 aspects of in vitro PHA stimulated immune response: (a) IL-2 receptor secretion, (b) IL-2 secretion, and (c) proliferation.

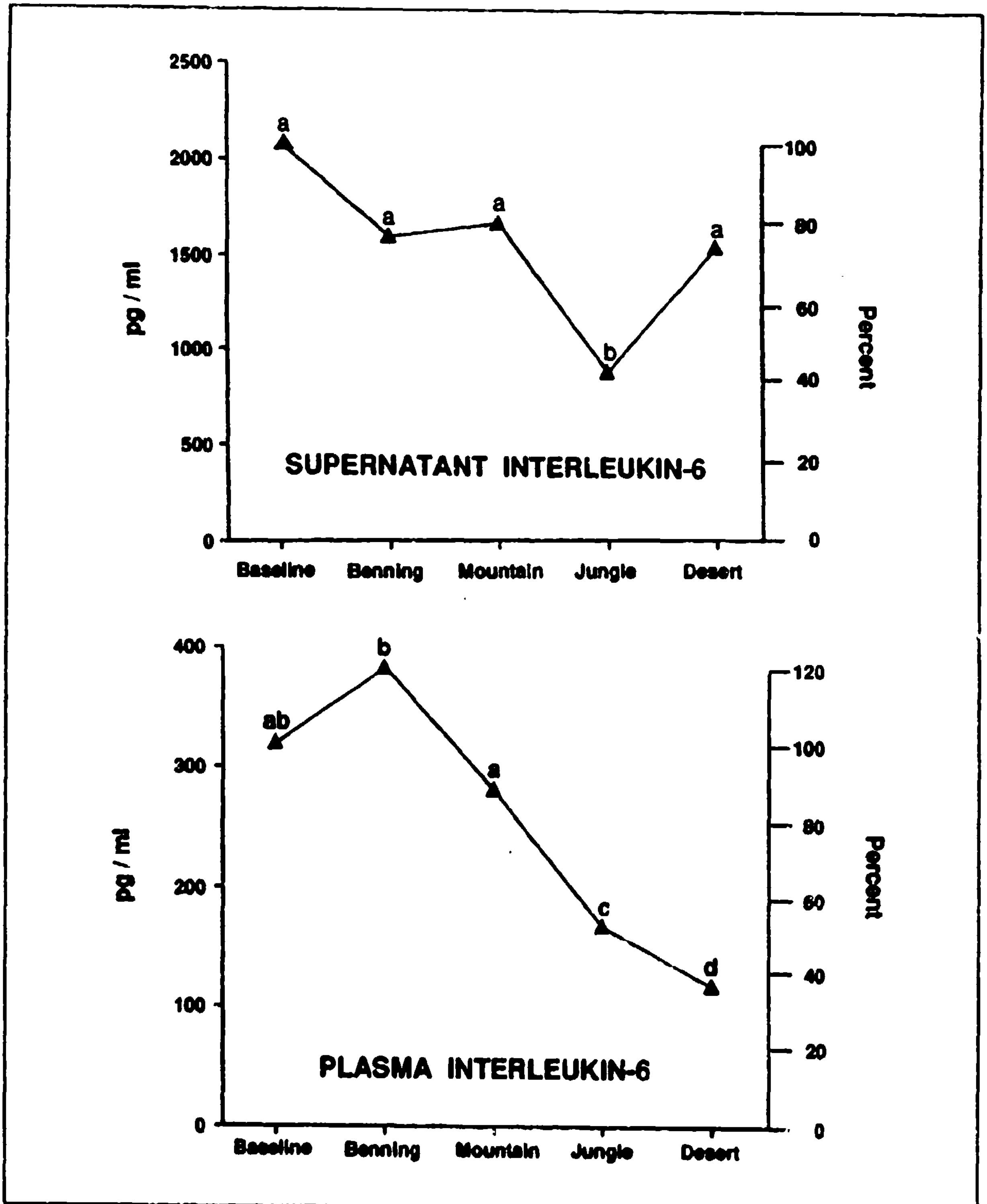


Figure 26. Production of IL-6 in unstimulated whole-blood cultures (upper graph) and plasma levels of IL-6 (lower graph), in samples collected through the course.

Table 25. Complete and Differential Blood Cell Counts of Soldiers During the Ranger Training Course[1,2,3]

Item[4]	Training Phase				
	Baseline	Benning	Mountain	Jungle	Desert
n	49	43[5]	46	44	51
WBC, x10³/µl	6.65±2.39	5.39±1.41**	8.17±3.01**c	7.42±2.04**b	6.97±1.95a
Neutrophils, x10³/µl	4.08±1.92	nd	6.17±2.77**	4.85±1.93**c	3.98±1.71c
Lymphocytes, x10³/µl	1.74±0.44	nd	1.22±0.31**	2.00±0.52**c	2.49±0.60**c
Monocytes, x10³/µl	0.51±0.23	nd	0.47±0.21	0.32±0.08**c	0.35±0.13**

[1]Mean±standard deviation; nd = not done.
[2]Significantly different from baseline: †p<0.10; *p<0.05; **p<0.01.
[3]Significantly different from preceeding phase: ap<0.10; bp<0.05; cp<0.01.
[4]RBC=red blood cells; Hb=hemoglobin; Hct=hematocrit; WBC=white blood cells.
[5]Differential counts not done.

CONCLUSIONS

The most significant finding in this descriptive study is that aspects of in vitro immune function are suppressed in the second half of Ranger training. This includes decreased T-lymphocyte function and suppressed systemic production of interleukin-6. This is the likely reason of increased infection rates during the second half of the course. Extensive exposure to pathogens during immersion in the swamps in the jungle phase increases the opportunity for infection and makes this a highly predictable period of infection risk, especially with respect to cellulitis of the lower extremities. Prolonged energy deficit is a likely cause of the reduction in immunocompetence, probably working through other deficits which are likely to include a shortage of proteins important in immune function.

The second most significant finding was the severity of weight loss even though much of it was represented by diminished fat stores. Based on anecdotal information and data collected in the 1977 Ranger nutrition study, we expected to see some individuals lose as much as 10% of their body weight. Instead we found that only 2 out of 55 finishers lost 10% of their body weight, with all others losing more. Since this includes a few relatively large losses from the muscle mass, this is excessive weight loss in exchange for the benefit of high stress training. Because the weight loss was so severe, the leanest soldiers in this study were clearly at a disadvantage compared to their fatter counterparts, an unusual finding for Army training. Compared to the earlier nutrition study, it indicates that, rather than becoming more lenient, as each generation of Ranger cadre is likely to claim, the course has become increasingly stressful, as the Commander suspected (Appendix I).

Soldiers can be challenged with hunger without producing greater than 10% weight loss and without having to stimulate more profound physiological (endocrine) responses which are triggered to preserve the fat-free mass. This could be produced at a slower rate of weight loss (ie. slightly more food across the course), or with better feeding throughout some phases such as the first phase when students are still learning basic techniques, or with better feeding in the initial "classroom" portion of each phase, when students are being taught instead of evaluated. This latter solution would make the course safer as well as more efficient if the lessons are better retained by students given adequate food (and sleep). The degree of food deprivation measured in this study is probably not generalizable to any anticipated modern-day combat scenarios and combat soldiers pushed to this level would likely find a way to supplement their diet. However, energy deficits are likely to occur during actual field

operations; therefore, future evaluations of ration design and body composition standards should acknowledge the importance of body fat reserves in meeting these deficits.

A third and very important finding from this study is that even with this amount of weight loss and the restricted availability of rations, the nutritional biochemistry remained so remarkably within normal limits. This included measures reflecting iron status and serum proteins. Several of the serum concentrations of vitamins rose from marginal levels at the start of the course to well within the normal range even as nonsupplementing soldiers continued on one ration/day for half of the time in the course, with samples collected at the end of the periods of restricted rations. This attests to the adequacy of the nutrient fortification of Army rations (particularly if the soldiers are driven to consume all components of the ration, as they were in this group). The measured nutrients, functional status and metabolites all point to the conclusion that Ranger students experience an uncomplicated energy deficit.

The results of this study agree with previous investigations of the influence of calorie restriction on health and performance. Restriction of energy intake, while providing adequate vitamins and minerals, results primarily in weight loss with some decrease in function related to muscle strength. The level of energy expenditure at any fixed level of energy restriction will in turn determine the severity and composition of the weight loss. On the other hand, starvation results in a reduced intake of all nutrients and can lead to a series of serious metabolic and functional changes. The situation that we observed during 8-1/2 weeks of Ranger training was consistent with restriction, but not true starvation. The primary consequences of the level of food intake and energy expenditure that we observed in this study were manifested as loss of lean body mass consistent with reduced maximum lift capacity and a possible compromise of the defense mechanisms of the immune system.

Unfortunately, the simple solution of a vitamin pill to correct an isolated deficiency or a second dose of penicillin to fortify the soldiers against infection have not turned out to provide the anticipated panacea. The best solution is to deal with the source of the problem, the imposed stressors. This study provides previously unavailable quantitative data to predict how much more food must be given for the same level of energy expenditure (i.e. in a summer class) to reduce the weight loss to around 10% of body weight. A smaller energy deficit may also improve immune function and lessen the soldiers' risk of infection and possible medical attrition from the course. The reduced weight loss will also help to moderate the nutritional stress

imposed on very lean soldiers by reducing the requirements which force catabolism of muscle tissue and, in turn, this will be a benefit to all soldiers completing Ranger training, in terms of their time to return to pretraining levels of physical strength and conditioning. The approach of limiting weight loss during Ranger training to approximately 10% will be examined in a 1992 summer class. If an improved immune status is demonstrated with this conservative modification, future changes in the plan of instruction and ration requirements in Winter classes can be monitored and adjusted to stay within the 10% limit.

In summary:

- o The results of the study suggest that this is an uncomplicated energy deficiency. There was no evidence of a vitamin or mineral deficiency despite reduced rations.

- o Weight loss was high but not severe enough to cause long term medical problems. It was high enough to produce some loss of muscle mass in nearly all students, necessitating a post-Ranger period of recovery to original fitness levels. The average duration of this recovery has not been defined but recovery appears to be complete by 6 months after the end of Ranger training.

- o Immunological response was compromised, probably due to the reduced plane of nutrition. The decreased T-lymphocyte function and suppressed systemic production of interleukin-6 indicate that Ranger students have a decreased protection against infectious disease. It is not known if these immune deficits are continuous during each phase, or if they recover in each phase when energy intake increases.

RECOMMENDATIONS

- The energy intake should be increased by approximately 500 kcal/day when only one ration per day is scheduled, or by approximately 300-400 kcal/day over the duration of the course. This will have little to no impact on the challenging nature of Ranger training but may substantially reduce the physiological and medical risk consequences. At the same energy expenditures, this would reduce the average weight loss to less than 10% and may attenuate the decrements in physical performance and in immune function. This change can be accomplished with minimal alterations to training by substituting the Long Life Ration Packet (LLRP; 1570 kcal) and a pouch bread supplement (240 kcal) for the MRE ration (1300 kcal).

- The effect of this intervention should be documented in a follow-on study.

- The nature and speed of recovery of Ranger trainees should be characterized in a follow-up study in the first 2-3 months following completion of the course.

REFERENCES

1. Keys A, Brozek J, Henschel A, Mickelsen O, Taylor HL: The Biology of Human Starvation. Minneapolis, MN: The University of Minnesota Press, 1950.

2. Headquarters, Ranger Training Brigade, Memorandum, 7 Aug 91, subject: Medical Support Requirements for Ranger Training Brigade (RTB).

3. Riedo FX, Schwartz B, Giono S, Hierholzer J, Ostroff S, Groover J, Musher D, Martinez L, Breiman R, and the Pneumococcal Pneumonia Study Group: Pneumococcal pneumonia outbreak in a Ranger Training Battalion. Program and Abstracts of the Interscience Conference on Antimicrobial Agents and Chemotherapy, Abstract #48. American Society of Microbiology, 29 Sept 1991, Chicago, IL.

4. Johnson HL, Krzywicki HJ, Canham JE, Skala JH, Daws TA, Nelson RA, Consolazio CF, Waring PP: Evaluation of calorie requirements for ranger training at Fort Benning, Georgia. Institute Report No. 34, Letterman Army Institute of Research, Presidio of San Francisco, CA, July 1976.

5. Pleban RJ, Valentine PJ, Penetar DM, Redmond DP, Belenky GL: Characterization of sleep and body composition changes during Ranger training. Military Psychology 1990;2:145-156.

6. Consolazio FC, Matoush LO, Nelson RA, Harding RS, Canham JE: Nutrition Survey: Ranger Department, Fort Benning, Georgia. Laboratory Report No. 291, US Army Medical Research and Nutrition Laboratory, Fitzsimmons General Hospital, Denver, CO, January 1966.

7. Hirsch E, Meiselman HL, Popper RD, Smits G, Jezior B, Lichton I, Wenkam N, Burt J, Fox M, McNutt S, Thiele MN, Dirige O: The effects of prolonged feeding Meal, Ready-to-Eat (MRE) operational rations. Technical Report NATICK/TR-85/035, US Army Natick Research, Development and Engineering Center, Natick, MA, October 1984.

8. US Department of the Army: Combat Field Feeding System - Force Development Test and Experimentation. Volume 1 - Basic Report. Technical Report CDEC-TR-85-006A. US Army Combat Developments Experimentation Center, Fort Ord, CA, January 1986.

9. Askew EW, Munro I, Sharp MA, Siegel S, Popper R, Rose MS, Hoyt RW, Martin JW, Reynolds K, Lieberman HR, Engell D, Shaw CP: Nutritional status and physical and mental performance of special operations soldiers consuming the Ration, Lightweight or the Meal, Ready-to-Eat military field ration during a 30 day field training exercise. Technical Report T7-87, US Army Research Institute of Environmental Medicine, Natick, MA, March 1987.

10. Cons‹‹‹o CF, Johnson HI, Nelson RA, Dowdy R, Krzywicki HJ, Daws TA, Lowry LK, Waring PP, Calhoun WK, Schwenneker BW, Canham JE: The relationship of diet to the performance of the combat soldier. Minimal calorie intake during combat patrols in a hot humid environment (Panama). Institute Report No. 76, Letterman Army Institute of Research, Presidio of San Francisco, CA, October 1979.

11. Crowdy JP, Consolazio CF, Forbes AL, Haisman MF, Worsley DE: The metabolic effect of a restricted food intake on men working in a tropical environment. Human Nutrition:Applied Nutrition 1982;36:325-344.

12. Headquarters, US Department of the Army: AR 40-25, Nutrition Allowances, Standards, and Education, 15 May 1985, Washington, D.C.: Government Printing Office.

13. Lichton IJ, Meyamura JB, McNutt SW: Nutritional evaluation of soldiers subsisting on Meal, Ready-to-Eat operational rations for an extended period: body measurements, hydration, and blood nutrients. American Journal of Clinical Nutrition 1988;48:30-37.

14. Opstad PK, Aakvaag A: The effect of high calory diet on hormanal changes in young men during prolonged physical strain and sleep deprivation. European Journal of Applied Physiology 1981;46:31-39.

15. Opstad PK, Aakvaag A: Decreased serum levels of oestradiol, testosterone and prolactin during prolonged physical strain and sleep deprivation, and the influence of a high calory diet. European Journal of Applied Physiology 1982;49:343-348.

16. Rognum TO, Vartdal F, Rodahl K, Opstad PK, Knudsen-Baas O, Withey WR: Physical and mental performance of soldiers on high- and low energy diets during prolonged heavy exercise combined with sleep deprivation. Ergonomics 1986;29:859-867.

17. Scrimshaw NS, Taylor CE, Gordon JE: Interactions of nutrition and infection. Monograph 57, World Health Organization, Geneva, 1968.

18. Keusch GT: Nutrition and Infection. In: Current Clinical Topics in Infectious Diseases (JS Remington, MN Swartz, eds.), New York: McGraw-Hill, 1984.

19. Beisel WR: Single nutrients and immunity. American Journal of Clinical Nutrition 1982;35 (suppl):417.

20. Gorse GJ, Messner RL, Stephens ND: Association of malnutrition with nosocomial infection. Infection Control and Hospital Epidemiology 1989;10:194-203.

21. Bondestam M, Foucard T, Gebre-Medhin M: Serum albumin, retinol-binding

protein, thyroxin-binding prealbumin and acute phase reactants as indicators of undernutrition in children with undue susceptibility to acute infections. Acta Paediatrica Scandinavica 1988;77:94-98.

22. Headquarters, US Department of the Army: FM 21-50, Ranger Training and Ranger Operations, January 1962.

23. Headquarters, US Department of the Army: AR 350-15, Army Physical Fitness Program, 3 November 1989, Washington DC: Government Printing Office.

24. Infantry School, US Department of the Army: SH 21-75, The Ranger Course Pamphlet, September 1989.

25. Headquarters, US Department of the Army: AR 70-25, Use of Volunteers as Subjects of Research, 25 January 1990, Washington DC: Government Printing Office.

26. Gordon CC, Bradtmiller B, Churchill T, Clauser CE, McConville JT, Tebbetts I, Walker RA: 1988 Anthropometric survey of U.S. Army personnel: methods and summary statistics. Natick Technical Report TR-89/044, U.S. Army Natick Research, Development & Engineering Center, Natick, MA, September 1989.

27. Durnin JVGA, J Womersley: Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition 1974;32:77-97.

28. Mazess RB, Barden HS, Bisek JP, Hanson J: Dual-energy x-ray absorptiometry for total body and regional bone mineral and soft tissue composition. American Journal of Clinical Nutrition 1990;51:1106-1112.

29. Friedl KE, De Luca JP, Marchitelli LJ, Vogel JA: Reliability of body-fat estimations from a four-compartment model using density, body water, and bone mineral measurements. American Journal of Clinical Nutrition 1992;55:764-770.

30. Ramos MU, Knapik JJ: Instrumentation and techniques for the measurement of muscular strength and endurance in the human body. Technical Report T2-80, US Army Research Institute of Environmental Medicine, Natick, MA, March 1978.

31. Teves MA, Wright JE, Vogel JA: Performance on selected candidate screening test procedures before and after Army basic and advanced individual training. Technical Report T13-85, US Army Research Institute of Environmental Medicine, Natick, MA, June 1985.

32. Schoeller DA: Measurement of energy expenditure in free-living humans by using doubly labeled water. Journal of Nutrition 1988;118:1278-1289.

33. Schoeller DA, Ravussin E, Shutz Y, Acheson KJ, Baertschi P, Jequier E: Energy expenditure by doubly labeled water: validation in humans and proposed calculations. American Journal of Physiology 1986;250:R823-R830.

34. Delany JP, Schoeller DA, Hoyt RW, Askew EW, Sharp MA: Field use of $D_2{}^{18}O$ to measure energy expenditure of soldiers at different energy intakes. Journal of Applied Physiology 1989;67:1922-1929.

35. Hoyt RW, Jones TE, Stein TP, McAninch G, Lieberman HR, Askew EW, Cymerman A: Doubly labeled water measurement of human energy expenditure during strenuous exercise. Journal of Applied Physiology 119;71:16-22.

36. Lifson N, McClintock R: Theory of use of the turnover rates of body water for measuring energy and material balance. Journal of Theoretical Biology 1966;12:46-74.

37. Nagy KA, Costa DP: Water flux in animals: analysis of potential errors in the tritiated water method. American Journal of Physiology 1980;238:R545-R465.

38. Fjeld, C.R., K.H. Brown, D.A. Schoeller. Validation of the deuterium oxide method for measuring average daily milk intake in infants. American Journal of Clinical Nutrition 1988;48:671-679.

39. Rose MS, Carlson DE: Effects of A-Ration meals on body weight during sustained field operations. Technical Report T2-87, US Army Research Institute of Environmental Medicine, Natick, MA, 1986.

40. Bayoumi RA, Rosalki SB: Evaluation of methods of coenzyme activation of erythrocyte enzymes for detection of deficiency of vitamins B1, B2, and B6. Clinical Chemistry 1976;22:327-335.

41. Vuilleumier RA, Keller HE, Keck E: Clinical chemistry methods for the routine assessment of vitamin status in human populations. Part III. The apoenzyme stimulation tests for vitamin B1, B2, and B6 adapted to the Cobas-Bio analyzer. International Journal of Vitamin and Nutrition Research 1990;60:126-135.

42. Sauberlich HE: Implications of nutritional status on human biochemistry, physiology and health. Clinical Biochemistry 1984;17:132-142.

43. Lundberg GD, Iverson C, Radulescu G: Now read this: the SI units are here. Journal of the American Medical Association 1986;255:2329-2339.

44. Lennette, EH, Balows, A, Hausler, WJ Jr., Shadomy, HJ. Manual of Clinical Microbiology, 4th Edition. American Society for Microbiology, Washington, DC., 1985.

45. Gunn BA, Ohashi DK, Gaydos CA, Holt ES: Selective and enhanced recovery of Group A and ß Streptococci from throat cultures with sheep blood agar containing sulfamethoxazole and trimethoprim. J Clin Microbiol 1977;5:650-655.

46. Baker JP, Detsky AS, Wesson DE, Wolman SL, Stewart S, Whitewell J, Langer B, Jeejeebhoy KN: Nutritional assessment - a comparison of clinical judgment and objective measurements. N Engl J Med 1982;306:969-972

47. SPSS, Inc. SPSS[x] User's Guide. New York:McGraw-Hill, 1983.

APPENDIX I

Statement of the Problem.

Memorandum: Nutrition/sleep study---Personal Reflections

COL John J. Maher III

31 January 1992

ATSH-RB (350) 31 January 1992

MEMORANDUM FOR RECORD

SUBJECT: Nutrition/Sleep Study--Personal Reflections

1. In my first three months of command of Ranger Training Brigade, I completed my initial assessment of the Ranger Course, with special emphasis on the stress applied to Ranger students. With normal concern for a high attrition course, a seeming increase in cellulitis and streptococcal cases, and extremely high medical attrition, I took a hard look at the condition of our Ranger students.

2. The students appeared to be a little more "starved" than I expected them to be. When we firmly enforced rules on contraband (extra food), it seemed that too many students took the risk of getting caught cheating. Were we feeding them enough? In reflection, I considered that the Course had been lengthened from 58 to 68 days, that with a fourth phase (desert), the students spent at least eight more days on a field training meal schedule (one a day), and that the MRE (in one of its many versions since 1983) had less calories than the old "C ration" I had in Ranger School. Perhaps we weren't giving students enough food, at least not on the summer meal schedule.

3. Given that our Brigade was focusing on converting admin time to training time within the program of instruction, and that attrition (especially medical attrition) was so high, I wanted to see if what we fed students was sufficient, in terms of caloric intake and nutrition. I was concerned that students might need an issued vitamin supplement. I also wanted to know if they needed a bicillin shot or a "booster" to reduce chance of infection (if their immune functions were too vulnerable). Lastly, I wanted to recheck the amount of sleep our students were getting, and see if the extra sleep given them before parachute operations was in fact doing what we thought in terms of safety.

4. In turning over the study to medical specialists, I reminded them of the purpose of our Course and the necessity of stressing the students with limited food and sleep. During field training exercises, it is extremely important for students to be stressed by a combinatin of constant performance evaluation, fatigue, hunger, and lack of sleep. However severe that stress may be, it must still be "reasonable." As a result (in summary), I asked the team to assess the condition of the students, tell me what was happening to their bodies while in the Course, and give

me information which could help me decide how much of what nutritional or vitamin supplements they needed. I asked them to determine if immunity was so vulnerable that bicillin or some other drug was necessary. Finally, I requested data on amount of sleep students were receiving throughout the Course.

JOHN J. MAHER III
Colonel, Infantry
Commanding

APPENDIX II

Description of the Ranger Course.

SH 21-75: The Ranger Course Pamphlet

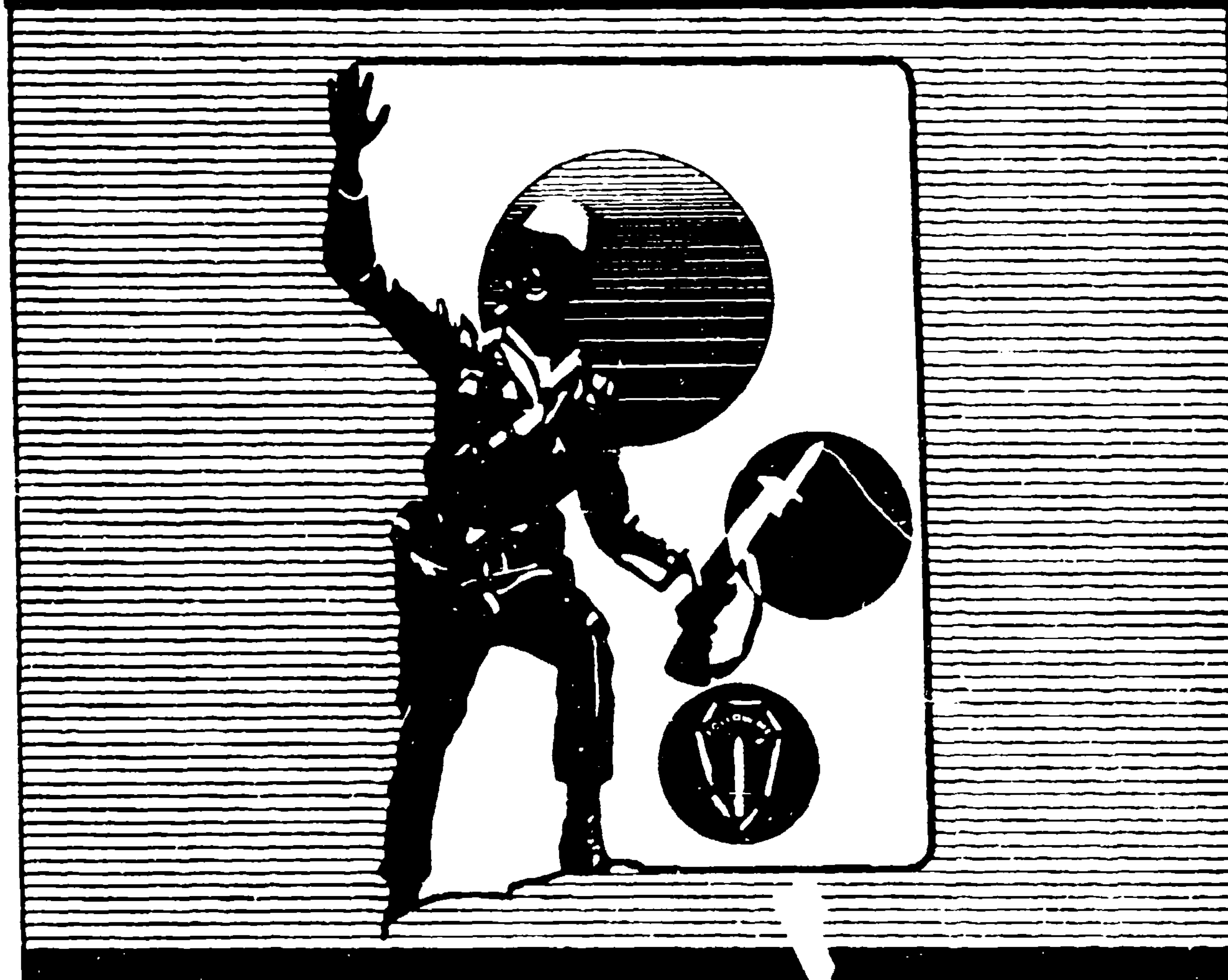
September 1989

Section I. Foreward
Section III. The Ranger Course
Section IV (A-F). Student Orientation

SH 21-75

THE RANGER COURSE PAMPHLET

PROPONENT: ATSH-R DATE: SEPT 1989



PREPARED BY

UNITED STATES ARMY INFANTRY SCHOOL

FORT BENNING, GEORGIA

SECTION I

FOREWARD

Unit and individual Ranger actions have contributed many courageous and daring exploits to the pages of American history. The story is a recurring one, depicting outstanding leadership coupled with the highest application of the skills used in the art of fighting.

Throughout the military history of the United States, Ranger units have been formed when needed and have accomplished their purpose with great credit. The American Ranger has built on what he inherited from the Rangers of the past. The present day Ranger is a man who is assigned to the 75th Infantry (Ranger) Regiment, the Ranger Training Brigade or is a graduate of the finest and most demanding leadership training in the United States Army today -- the U.S. Army Ranger Course conducted at Fort Benning, Georgia.

This pamphlet addresses the Ranger Course, a course of instruction which develops highly confident, tough and capable small unit leaders. The current approach to the Ranger Course, training individuals rather than units, was initiated in October 1951, when the United States Army Infantry School established the Ranger Course at Fort Benning.

The Ranger Course affords the junior leader opportunity, by practical application, to develop and to prove himself in a rugged course of instruction. It is stress-oriented and develops within the Ranger student the ability to lead and command under heavy mental, emotional and physical stress. The emphasis is on practical, realistic and strenuous field exercises using the Infantry rifle squad and rifle platoon as the training vehicle to accomplish this development.

The Ranger Course is taught using the most current tactical doctrine; additionally, emphasis is placed on developing military skills in the planning and conduct of dismounted, airborne, airmobile and waterborne squad and platoon-sized operations.

This pamphlet has been designed to acquaint the prospective Ranger student with the history of the American Ranger and the Ranger Course. Furthermore, it has been designed to familiarize the commander with the final product of the Ranger Course and how he, the commander, can profit when his junior leaders earn the coveted United States Army Ranger tab.

SECTION III

THE RANGER COURSE

1. GENERAL

The soldier who has experienced combat knows the value of tough, realistic training in leadership and military skills. He knows that he must be able to successfully accomplish any mission which his unit has been organized, equipped and trained to perform in the shortest possible time, with the least expenditure of resources (men and equipment) and with the least confusion to maintain a combat effective unit. The Ranger Course provides tough, realistic training with a minimum of formal classroom instruction.

2. PURPOSE

The Ranger Course develops the leadership skills of selected male officers and enlisted personnel by requiring them to perform effectively as small unit leaders in a realistic, tactical environment under mental and physical stress approaching that found in combat. It provides the student with practical experience in the application of the tactics and techniques of Ranger operations in wooded, mountainous, lowland swamp and desert environments. Emphasis is placed on development of individual leadership abilities through the application of the principles of leadership while further developing military skills in the planning and conduct of dismounted infantry, airborne, air assault and amphibious squad and platoon-size combat operations.

Ranger students negotiating the log walk/rope drop at Victory Pond.

3. SCOPE

The Ranger Course is 65 days in length with an average of 19.6 hours of training each day, 7 days a week. It is divided into 4 phases of training with each phase being conducted at a different geographical location. The first (Benning Phase), 17 days in length, is conducted by the 4th Battalion, Ranger Training Brigade (RTB) at Fort Benning, Georgia. The second (Mountain Phase), 16 days in length, is conducted by the 5th Battalion, Ranger Training Brigade at Camp Frank D. Merrill near Dahlonega, Georgia. The third (Florida Phase), 16 days in length, is conducted by the 6th Battalion, Ranger Training Brigade at Camp James E. Rudder at Eglin AFB, Florida. The fourth (Desert Phase), 14 days in length, is conducted by the 7th Battalion, Ranger Training Brigade at Dugway Proving Ground, Utah. Two days of the course are consumed by maintenance, in/out processing and graduation. Rangers are assigned to one of the three Ranger Training Companies of the 4th Battalion upon arrival at Fort Benning and will be trained by that unit's cadre utilizing Small Group Instruction (SGI) techniques throughout the phase. Upon rotating through the other phases, the same procedures are followed.

The emphasis during the course is on practical, realistic, and strenuous field training, where the Ranger student will be taught Ranger-related skills based on current tactical doctrine. It is a leadership course for small-unit leaders in which the student is exposed to conditions and situations which closely approximate and often exceed those he would encounter in combat. Fatigue, hunger, the necessity for quick, sound decisions and the requirement for demonstrating calm, forceful leadership under conditions of mental and emotional stress are all contained within the Ranger Course.

A Ranger student briefs his subordinates on the route while learning the fundamentals of combat operations.

The instruction is conducted with units that vary in size from an infantry rifle squad to a rifle platoon, in distance traveled from 2 to 30 kilometers, and in duration from 1 to 5 days.

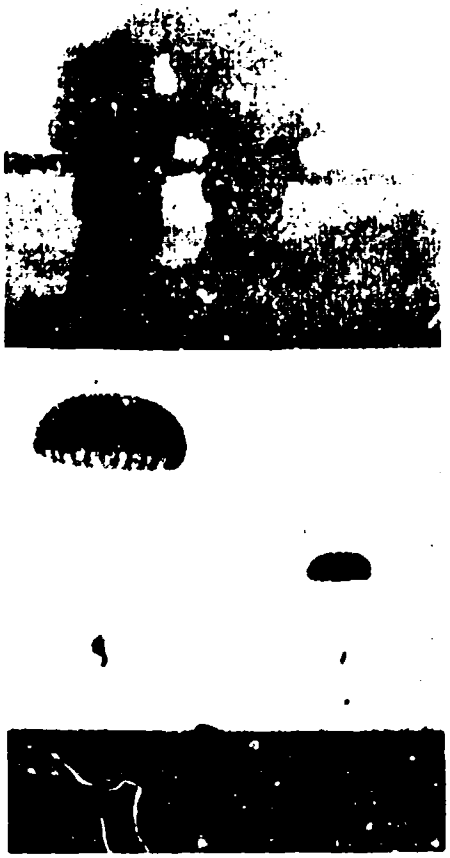
The qualified Ranger leader has been trained to effectively lead under conditions of simulated combat stress. He is evaluated as a small-unit leader in a series of field training exercises which are conducted primarily at night, under any weather conditions. Live-fire exercises are conducted in the Florida and Desert Phases. Frequent and unexpected enemy contact, reduced sleep, difficult terrain and the constant pressure of operating within restrictive time limits all contribute to this atmoshpere of stress.

4. THE BENNING PHASE

The Benning Phase of Ranger training is designed to develop the military skills, physical and mental endurance, stamina, and confidence a small-unit combat leader must have to successfully accomplish a mission. It is also designed to teach the Ranger student to properly maintain himself, his subordinates, and his equipment under difficult field conditions during the subsequent phases of Ranger training. However, if the student is not already in TOP PHYSICAL CONDITION when he reports to the Ranger Course, he will have extreme difficulty keeping up with the fast pace of Ranger training, especially during the initial phase.

The Benning Phase is executed in two parts. The first is conducted in the Harmony Church area and consists of a demanding advanced physical training program and training in the skills necessary to conduct extended combat operations. The PT program consists of runs of 3 to 5 miles, combatives (hand-to-hand combat), and tactical road marches. Advanced physical training assures physical and mental endurance and the stamina required for enhancing the basic Ranger characteristics--leadership, confidence and toughness. Technique training includes: map reading, airborne operations, leadership, land navigation, medical considerations, environmental and survival-type training.

The second portion of the Benning phase is conducted at nearby Camp William O. Darby. The emphasis at Camp Darby is on the instruction and execution of combat operations. The Ranger student receives instruction in the fundamentals of combat operations, to include battle drills, principles and techniques that enable his unit to successfully conduct reconnaissance and ambush-type missions. The Ranger will then be afforded the opportunity to demonstrate his expertise through series of cadre and student led tactical operations. As a result, the Ranger student will gain tactical and technical proficiency, confidence in himself and be prepared to move to the next phase of the course--the rugged Mountain phase.



Students making combat parachute assault.

Ranger students under the watchful eyes of a Ranger instructor.

5. THE MOUNTAIN PHASE

During the Mountain Phase of training, the student gains additional tactical proficiency in the fundamentals, principles and techniques of employing small combat units in a mountainous environment. He further develops his ability to lead squad-sized units and to exercise control through the planning, preparation, and execution phases of all

types of unit operations, including ambushes and raids, plus environmental and survival techniques. The Ranger student continues to improve his ability to maintain himself and his equipment for extended periods in the field with only limited support. The Ranger student becomes aware of his capabilities and limitations due to the continuous challenges he encounters on a daily basis from severe weather, rugged terrain, periods of hunger, mental and physical fatigue, as well as emotional stress.

Air Assault operations at the Mountain Ranger Camp.

Day and night missions are directed against a conventional threat force. These missions are from two to five days in duration and culminate in a series of combat missions where the unit will infiltrate the threat forward security area, move cross-country over the mountains, cross the rapid Toccoa River, conduct night vehicular ambushes, raid threat missile sites, and continue operations in the threat force rear area for an extended period of time. Leadership is tested to the maximum extent, in that any Ranger Student may be appointed at any time to lead tired, hungry Ranger students to accomplish the mission.

Student giving operation order.
Mountain Phase

In addition to his instruction in combat operations and field exercises, the student receives instruction in military mountaineering techniques which instill a high degree of confidence in himself and his fellow students. He learns the fundamentals of rope work, the methods of mountain rappelling, rock climbing, and finally, permanent and semi-permanent rope installations. Party climbing, balance climbing, direct aid climbing, and a 200-foot night rappel on Yonah Mountain culminate the instruction, allowing the Ranger student to fully apply the instruction he has received in a tactical military mountaineering operation during the Field Training Exercise (FTX).

Military mountaineering on Mount Yonah.

At the conclusion of the Mountain Phase, the student moves to the next phase of training, the Florida Phase, conducted at Eglin AFB, Florida.

5. THE FLORIDA PHASE

The third phase of Ranger school is at Camp James E. Rudder (Auxiliary Field #6), Eglin AFB, Florida. Emphasis during this phase is to continue the development of small unit leaders, capable of operating effectively under conditions of extreme mental and physical stress. This will provide the Ranger student with practical experience in extended platoon level operations in a jungle/swamp environment. The training further develops the students' ability to plan for and lead small units on independent and coordinated airborne, air assault, amphibious (LCM-8), small boat, and dismounted combat operations in a mid-intensity combat environment against a well-trained, sophisticated enemy.

Extended platoon operations in the jungle/swamps of the Florida Ranger Camp.

The Florida Phase begins by providing the student with a realistic scenario in which the unit has simulated a deployment into a fictitious country. As the scenario develops, the students receive "in-country" technique training that will assist them in accomplishing the tactical missions later in the phase. Technique training includes: small boat operations, expedient stream crossing, employment of AC 130 (Spectre Gunship), and techniques of surviving and operating in a jungle/swamp environment.

As the technique training is being conducted, the Ranger students are updated on the sequence of events in the scenario that ultimately will cause the unit to be committed to combat. The 8-day FTX is a fast-paced, highly stressful, challenging exercise where the students are trained and evaluated on the application of small unit tactics and leadership skills. To successfully accomplish the missions they receive (raids and ambushes) the student is required to apply the principles of leadership and combat techniques learned in the first three phases of Ranger training. The integration of live-fire training further challenges leadership skills in a tactically realistic scenario.

Small boat operations.

Stream crossing operations.

Amphibious Operations in the Gulf of Mexico

7. THE DESERT PHASE

Ranger students move to Dugway, Utah for the Desert Phase, the fourth and final phase, by C-141 and C-130 aircraft, under control of the 7th Battalion cadre. In-flight parachute rigging is conducted and airborne Ranger students conduct a parachute assault/airfield seizure into the Utah desert south of the Great Salt Lake. (Non-airborne Ranger students are air-landed.) In this phase, considered a graduate level of the Ranger Course, the Ranger student encounters a harsh desert environment as well as an aggressive enemy force. He learns to survive and conserve his energy during the extreme heat of the summer or cold of winter (temperatures range from 115 degrees to - 60 F) through his leadership abilities, and by optimizing the capabilities of his equipment. He learns to move long distances at night across the desert, navigating by terrain features, the compass and stars. Ranger students spend 14 days conducting desert combat operations learning desert survival skills and conducting force-on-force operations with MILES equipment, live-fire raids and ambushes. The live-fire exercises are considered the capstone event for the Ranger student and will further develop his leadership skills.

Upon completion of the Desert Phase the Ranger students will board C141/C130 aircraft, conduct in-flight rigging and jump into Fryar DZ, Fort Benning, Georgia. He will graduate two days later if he has met the challenge and passed all the requirements demanded in the Ranger Course.

Operations order prior to move out on a desert combat operation.

8. SUMMARY

High standards are required and maintained in a stressful environment in Ranger training. The Ranger Course produces a man who is a tough and confident leader who can lead small units under adverse conditions, including the effects of extended mental and physical stress, and successfully accomplish his mission. He has also proven during the Ranger course that he can overcome seemingly insurmountable mental and physical challenges. He has demonstrated, while under simulated combat conditions, that he has acquired the professional skills and techniques necessary to plan, organize, coordinate, and lead a small unit. He has also displayed that he has mastered basic skills in leadership, dismounted small-unit night operations, demolitions, hand-to-hand combat, low altitude mountaineering, and unique infiltration and exfiltration techniques via land, air, and sea. As a result of proving that he can successfully accomplish these tasks during the Ranger Course, he is authorized to wear the coveted Ranger tab. The graduate of the Ranger Course is the epitome of military competence and efficiency in all Infantry skills.

Ranger receiving the coveted "Ranger Tab" during
Ranger Class graduation ceremony

Ranger Graduation at Todd Field

SECTION IV

STUDENT ORIENTATION

A. GENERAL

The following information is intended to answer typical questions for the prospective Ranger student.

1. The Ranger Training Brigade trains students from all services of the United States Armed Forces and many allied countries. No insignia of rank is worn by students during the course; all students are addressed as "Ranger".

2. Throughout the course the "Buddy System" is used to instill a spirit of teamwork and cooperation. Each Ranger student must know his buddy's location and welfare at all times throughout the course.

3. U.S. Army graduates of the Ranger Course are awarded an Additional Skill Identifier (ASI) or an MOS suffix letter.

a. Airborne qualified officer graduates are awarded the ASI 5S; airborne qualified enlisted graduates are awarded the MOS letter V.

b. Non-airborne officer graduates are awarded the ASI 5R; non-airborne enlisted graduates are awarded the MOS suffix letter G.

B. PREREQUISITES

1. Officers of any branch and noncommissioned officers may apply by submitting a DA Form 4187 through their unit. Ranger course applications are managed at Department of the Army through the Army Training Requirements Resource System (ATRRS). Enlisted applicants below the grade of E-5 must submit a request for waiver of NCO grade to the applicant's first O6 Commander in the Chain of Command. Waiver will include the most recent APFT results, and time served in leadership positions. The request for waiver must be endorsed by the individual's company and battalion commander. Approved waivers must accompany applications for quotas to the Ranger Course.

2. Individuals must be male and must volunteer for the course.

3. All personnel must possess a medical examination dated within 18 months of their reporting date stating that the applicant is medically qualified to attend Ranger School. Record of this must be brought by the individual when he reports for training. Individuals must bring their health records. Health records must include a statement signed by the commander verifying that the individual has had a panorex made and can be made available by the sending unit, if required.

4. Army Physical Fitness Test (APFT) and Combat Water Survival Test (CWST). Applicants must take the APFT and CWST within 30 days of application. The APFT and CWST should be administered by a Ranger assigned to that Division/Brigade/Battalion and the report of results, signed by him, will accompany the student when reporting for enrollment. All students will be required to take the APFT and CWST upon their arrival to the Ranger Training Brigade.

a. APFT. The APFT will be conducted IAW FM 21-20 with changes. The standard, regardless of age, for entrance into the Ranger Course is a minimum of 52 pushups, 62 situps, and the two mile run in running shoes in 14 minutes, 54 seconds or less. In addition, applicants must execute 6 chin-ups (palms facing toward the face).

b. CWST. The CWST consists of three events.

(1) THE 15-METER SWIM: Swim 15 meters with rifle, wearing fatigues, boots, and web equipment (pistol belt, suspenders, two ammunition pouches, two full canteens), without loss of rifle or equipment and without showing unusual signs of fear or panic.

(2) EQUIPMENT REMOVAL: Enter water from poolside. Submerge and remain under water, discard rifle and remove web equipment (as above), surface, and swim to poolside without showing unusual signs of fear or panic.

(3) THE 3-METER DROP

5. An applicant to the Ranger Course must demonstrate knowledge and be CERTIFIED by his unit commander in the 37 military entry skills specified in Special Information paragraph 4. The Commander's certification must accompany the applicant and be turned in during inprocessing. Ranger applicants are liable for random sample testing at the discretion of the Ranger Training Brigade Commander.

6. Enlisted applicants must have a standard score of 90 or higher in aptitude area CO and 18 months or more of active duty service remaining after the completion of the course.

7. No security clearance is required.

8. No additional obligated service is incurred by active Army commissioned officers for attending the course.

9. Students are not required to be airborne qualified.

10. Failure to bring evidence of completion of prerequisite skills and requirements when reporting for the training may result in nonenrollment.

C. SPECIAL INFORMATION

1. The Ranger Program performance statistics for the fiscal year 1988 showed the highest rate of attrition occured during the first five days of training. During days 1-5, all evaluations are objective in nature and examine prerequisite skill proficiency. In order to better prepare yourself for Ranger School a generic outline of the first five days of Ranger School is listed below: See Physical Training Standards - Section VI.

a. Day 0 - INPROCESS

(1) Event - APFT. Standards: 52 pushups in 2 minutes; 62 situps in 2 minutes; 2-mile run in 14:54 minutes or less; and 6 chinups, no time limit.

(2) Event - CWST. Standards: 15 memter swim, 3 meter drop and equipment removal.

(3) Average Sleep: 5 hours.

b. Day 1

(1) Event - Hand-to-Hand Training.

(2) Event - Confidence Test. Standards: Complete low crawl, horizontal ladder, rope climb, vertical climb.

(3) Event - Basic Map Review and Terrain Association.

(4) Event - Road March. Standards: 5 miles in 1 hour and 30 minutes.

(5) Event - Medical Consideration Class.

(6) Event - Hand-to-Hand Training.

(7) Average Sleep: 4 hours.

c. Day 2

(1) Event - PT. Standards: 5 mile run in 4Ø:15 or less after PT IAW FM 21-2Ø.

(2) Event - Technique Training (Warning Orders/OPORD Classes).

(3) Event - Rangers-In-Action Demonstration.

(4) Event - Water Confidence Test. Standards: Log walk/rope drop and suspension traverse.

(5) Event - Technique Training (Warning Orders/OPORD Classes continued).

(6) Event - Hand-to-Hand Training.

(7) Average Sleep: 4 hours.

d. Day 3

(1) Event - PT. Standards: 3 mile run in 24:15 or less after PT IAW FM 21-2Ø.

(2) Event - Day Land Navigation Exam. Standards: Must find 4 out of 6 points in 5 hours.

(3) Event - Patrol Base Training.

(4) Event - Night Land Navigation Exam. Standards: Must find 3 out of 4 points in 3 hours.

(5) Average Sleep: 5 hours.

e. Day 4

(1) Event - PT. Standards: 4 mile run in 32:15 or less. after PT IAW FM 21-2Ø.

(2) Event - Airborne Refresher Training.

(3) Event - Conduct Airborne/Assault Operations.

(4) Event - Land Navigation Retest.

(5) Event - Establish Patrol Base/Patrol Base Operations

(6) Average Sleep: 4 hours.

f. Day 5

(1) Event - 4 mile run/5 mile retest.

(2) Event - Operational techniques classes.

2. All applicants planning to attend this instruction should be briefed on the Ranger Course by a Ranger-qualified officer or NCO prior to making application.

3. All Commanders must ensure that applicants are in top physical condition when reporting for the Ranger Course. Due to the extreme temperatures and humidity at Fort Benning, Ga., during the summer season it is recommended that students take advantage of the zero week offered for classes 8 thru 11. They would report on Saturday NLT 1200 hours on the week prior to their original reporting date. Commander MUST screen their personnel to ensure that personnel with previous cold weather injuries not attend classes 1 thru 5 and those personnel with previous heat injuries not attend classes 8 thru 11. Personnel attending those classes with previous heat or cold weather injuries will be immediately dropped from the course and sent back to their home stations. Applicants should concentrate on improving upper body strength and road marching in properly fitted boots, with a full rucksack, for distances up to 15 miles.

4. The following 37 tasks are necessary military skills needed for successful completion of the Ranger Course and all applicants should be proficient in each. A certificate of proficiency must be signed by the unit commander and must accompany each applicant.

(1) "Perform Mouth-to-Mouth Resuscitation"

STP 21-1 (SMCT)
Task No: 081-831-1042
Ref: FM 21-11

(2) "Put on a Field or Pressure Dressing"

STP 21-1 (SMCT)
Task No: 081-831-1016
Ref: FM 21-11

(3) "Put on a Tourniquet"

STP 21-1 (SMCT)
Task No: 081-831-1017
Ref: FM 21-11

(4) "Prevent Shock"

STP 21-1 (SMCT)
Task No: 081-831-1005
Ref: FM 21-11

(5) "Give First Aid for Burns"

STP 21-1 (SMCT)
Task No: 081-831-1007
Ref: FM 21-11

(6) "Call For/Adjust Indirect Fire"

STP 7-11B24, SM, July 1985
Task No: 061-283-6003
Ref: FM 6-30

TEC Lessons:
949-061-0111A
949-061-0112A
949-061-0113A

(7) "Camouflage Yourself and Your Individual Equipment"

STP 21-1 (SMCT)
Task No: 051-191-1361
Ref: FM 5-20, TC 5-200, FM 21-75, TEC 937-061-0030-F,
TEC 937-061-0031F

(8) "Camouflage Your Defensive Position"

STP 21-1 (SMCT)
Task No: 051-202-1363
Ref: FM 21-75
FM 5-103

(9) "Select Temporary Fighting Positions"

STP 21-1 (SMCT)
Task No: 071-326-0513
Ref: FM 21-75

TEC Lesson: 010-071-1044F

(10) "Construct Individual Fighting Position"

STP 21-1 (SMCT)
Task No: 071-326-5703
Ref: FM 7-8

TEC Lessons: 040-071-1045 and 1046

(11) "Clear Fields of Fire"

STP 21-1 (SMCT)
Task No: 071-331-0852
Ref: FM 7-7
FM 7-8

(12) "Use Challenge and Password"

STP 21-1 (SMCT)
Task No: 071-331-0801
Ref: FM 21-75
FM 22-6

TEC Lesson: 935-071-1029F, Counter-Intelligence

(13) "Collect/Report Information - SALUTE"

STP 21-1 (SMCT)
Task No: 071-331-0803
Ref: FM 21-75

TEC Lesson: 935-071-1026F

(14) "Conduct Day and Night Surveillance Without the Aid of Electronic Devices"

STP 21-1 (SMCT)
Task No: 071-331-0804
Ref: FM 21-75

(15) "Operate Radio Set AN/PRC-77"

STP 7-11B1, SM
Task No: 113-587-2044
Ref: TM 11-5280-667-12
TM 11-5820-498-12
TB Sig 291

(16) "Identify Terrain Features on a Map"

STP 21-1 (SMCT)
Task No: 071-329-1001
Ref: FM 21-26

TEC Lesson: 930-071-0013F
930-071-0016F

(17) "Determine the Grid Coordinates of a Point on a Military Map Using the Military Grid Reference System"

STP 21-1 (SMCT)
Task No: 071-329-1002
Ref: FM 21-26

TEC Lesson: 930-071-0013F
GTA 5-2-12

(18) "Determine a Magnetic Azimuth Using a Compass"

STP 21-1 (SMCT)
Task No: 071-329-1003
Ref: FM 21-26

TEC Lesson: 930-071-0017F

(19) "Determine the Elevation of a Point on the Ground Using a Map"

STP 7-11B24, SM
Task No: 071-329-1004
Ref: FM 21-26

TEC Lesson: 930-071-0016F

(20) "Determine a Location on the Ground by Terrain Association"

STP 21-1 (SMCT)
Task No: 071-329-1005
Ref: None

TEC Lessons: 930-071-0018F
930-071-0163F

(21) "Navigate from One Position on the Ground to Another Point, Dismounted"

STP 21-1 (SMCT)
Task No: 071-329-1006
Ref: FM 21-26

TEC Lessons: 930-071-0013F
930-071-0016F
930-071-0018F
930-071-0165F

(22) "Measure Distance on a Map"

STP 21-1 (SMCT)
Task No: 071-329-1008
Ref: FM 21-26

TEC Lesson: 930-071-0014F

(23) "Convert Azimuth (Magnetic or Grid)"

STP 7-11B24, SM
Task No: 071-329-1009
Ref: FM 21-26
TC 21-26

TEC Lesson: 930-071-0015F

(24) "Determine Azimuths Using a Protractor and Compute Back Azimuths"

STP 7-11B24, SM
Task No: 071-329-1031
Ref: FM 21-26

TEC Lesson: 930-071-0014F

(25) "Orient a Map Using a Compass

STP 7-11B24, SM
Task No: 071-329-1011
Ref: FM 21-26

(26) "Orient a Map to the Ground by Map-Terrain Association"

STP 21-1 (SMCT)
Task No: 071-3290-1012
Ref: FM 21-26

(27) "Locate an Unknown Point on a Map or on the Ground by Intersection"

STP 7-11B24, SM
Task No: 071-329-1014
Ref: FM 21-26

TEC Less : 930-071-0019

(28) "Locate an Unknown Point on a Map or on the Ground by Resection"

STP 7-11B24, SM
Task No: 071-329-1015
Ref: FM 21-26

TEC Lesson: 930-071-0019

(29) "Construct a Nonelectric Demolition Firing System"

STP 7-11B24, SM
Task No: 051-193-1002
Ref: FM 5-25
FM 5-34
TM 9-1375-213-12

TEC Lesson: 946-093-7601F

(30) "Construct an Electric Firing System"

STP 7-11B24, SM
Task No: 051-193-1004
Ref: FM 5-25
FM 5-34
TM 946-093-7602F

TEC Lesson: 946-093-7602F

(31) "Install US Firing Devices on Standard Military Explosives"

STP 7-11B24, SM
Task No: 051-193-1010
Ref: FM 5-25

(32) "Clear Nonelectric Misfires"

STP 7-11B24, SM
Task No: 051-193-2019
Ref: FM 5-25

(33) "Clear Electric Misfires"

STP 7-11B24, SM
Task No: 051-193-2020
Ref: FM 5-25

(34) "Practice Preventive Medicine"

STP 7-11B1, SM
Task No: 071-328-5303
Ref: FM 21-10

TEC Lessons: 929-441-0042F
929-441-0043F
911-441-0034F
911-441-0035F

(35) "Control Rate and Distribution of Fire"

STP 7-11B24, SM
Task No: 071-326-5501
Ref: FM 7-8

TEC Lesson: 010-071-1057F

(36) "Prepare and Issue an Oral Squad Operation Order"

STP 7-11B24, SM
Task No: 071-326-5505
Ref: FM 100-5
FM 101-5
FC 7-5

(37) NOTE: Volunteers should be able to complete a road march in accordance with the standards specified in the DA Circular for Expert Infantryman's Badge; additional reference: FM 21-18, Foot Marches.

D. STUDENT EVALUATION SYSTEM

1. Leadership Evaluation:

a. Each student will be evaluated on his abilities as a small unit leader on a continuous basis throughout the Ranger course. Leadership will be evaluated based upon how effectively the student influences his subordinates and uses available resources in accomplishing all assigned tasks and missions. Specific requirements are listed below.

b. The following areas will be used in evaluating a student during the Ranger course to determine successful completion of the course:

(1) Combat operations/Leadership Evaluation - Each student will be evaluated at least once in each phase in combat operations/leadership and must receive a "GO" in these evaluations. Of these, at least one combat operation in the Mountain Phase, one in the Florida Phase and Desert Phase must be passed. One of these graded combat operations must be in a primary leadership position. In order to graduate, a student must maintain a 50 percent pass rate in all graded evaluations.

(2) Skill Evaluations - Each student must receive a "GO" in the two events listed below according to the specific standard. Any student who receives a "NO GO" in any of the events may be eliminated or recycled immediately.

a. Ranger Runs - Each student must successfully complete three of the four graded runs, one of which is a five mile run that MUST be completed to receive a "GO" in this event.

b. Terrain Navigation - Each student must correctly negotiate the terrain navigation course in order to receive a "GO" in this event. One retest during the Benning Phase will be allowed. Failure of the retest may result in termination from the course or recycle.

(3) Mountaineering Performance Test - Each student must tie correctly at least 8 of 12 knots and pass the Belay test to receive a "GO" in this event.

(4) Confidence Test - Each student must successfully accomplish each of the events listed below. Any student who does not successfully accomplish an event or refuses to attempt it may be eliminated from the course immediately.

a. Log Walk/Rope Drop (Benning Phase).

b. Suspension Traverse (Benning Phase).

c. Darby Queen (Benning Phase).

d. 200-foot Night Rappel (60-foot Night Rappel during severe weather) (Mountain Phase).

(5) Critical Incident Report (CIR) - These reports are established to provide an additional means of evaluating student performance primarily in a non-graded position. They reflect both good and bad performance. They are divided into four categories: major satisfactory, minor satisfactory, major unsatisfactory and minor unsatisfactory. Three minor CIRs are equivalent to one major CIR. Any major or minor satisfactory CIR will have the effect of cancelling a major or minor unsatisfactory CIR, respectively. Three major or equivalent minor unsatisfactory CIRs could warrant recycle or relief from the course.

(6) Special Observation Report (SOR) - An unsatisfactory SOR is grounds for dismissal. No student with an approved SOR will be allowed to progress to the next phase.

(7) Peer Evaluations - Students will receive a Peer Evaluation at the end of each phase of training. A score of 60% on each peer evaluation must be attained in order to receive a "GO". Failure to attain a passing score on 2 of 4 peer evaluations will cause the students academic records to be reviewed to determine his disposition, i.e., continue in the course, recycle or drop from the course.

(8) Each student will not miss more than 72 hours of training during the entire Ranger Course.

c. At the end of each of the successive phases (Benning, Mountain, Florida and Desert) of the Ranger Course, the battalion chain of command and the Battalion Commander responsible for the phase will review academic records to determine eligibility for remaining in the course. The Battalion Commander will make a recommendation to the Brigade Commander for final decision on relief, recyce or continuation of any student with substandard performance. The following guidelines will be used in evaluating students after each of the respective phases:

(1) Benning Phase - 4th Battalion, Ranger Training Brigade

(a) A student must pass all of the following skill evaluations:

1. Ranger Runs.

2. Terrain Navigation.

3. Confidence Tests.

(b) Each student will attend 75% or more of each of the following instruction:

1. Combatives.

2. Technique Training and Cadre Led combat operations.

(c) Each student must successfully negotiate the Darby Queen, Log Walk/Rope Drop, and the Suspension Traverse.

(d) Academic files of students who have received three major or equivalent minor unsatisfactory CIRs will be reviewed by the Battalion Commander to determine their disposition.

(e) Any student who receives an approved unsatisfactory SOR will not be allowed to continue to the Mountain Phase.

(f) Each student must successfully pass the end of phase peer evaluation.

(2) Mountain Phase - 5th Battalion, Ranger Training Battalion.

(a) A student must pass one leadership evaluation in the Mountain Phase.

(b) Each student must demonstrate proficiency in Mountaineering techniques.

(c) Each student must successfully negotiate the 200-foot night rappel (60-foot night rappel during severe weather).

(d) Any student who has accumlated three major or equivalent minor unsatisfactory CIRs will have his academic file reviewed by the Battalion Commander to determine the student's disposition.

(e) Any student who receives an approved unsatisfactory SOR will not be allowed to continue to the Florida Phase.

(f) Each student must successfully pass the end of phase peer evaluation.

(3) Florida Phase - 6th Battalion, Ranger Training Brigade.

(a) A student must pass one leadership evaluation in the Florida Phase.

(b) Any student who has accumulated three major or equivalent minor unsatisfactory CIRs will have his academic files reviewed by the Battalion Commander to determine the student's disposition.

(c) Any student who receives an approved unsatisfactory SOR will not be allowed to continue to the Desert Phase.

(d) Each student must successfully pass the end of phase peer evaluation.

(4) Desert Phase - 7th Battalion Ranger Training Brigade.

(a) One leadership evaluation must be passed in the Desert Phase.

(b) A student must participate in 80% of the live-fire ambush/raid operations.

(c) Any student who has accumulated three major or equivalent minor unsatisfactory CIRs will have his academic files reviewed by the Battalion Commander to determine the student's disposition.

(d) Any student who receives an approved unsatisfactory SOR will not be allowed to graduate.

(e) Each student must successfully pass the end of phase peer evaluation.

2. Honor Graduate:

a. The following prerequisites will be used in selecting the Honor Graduates for the Ranger Course:

(1) Meet the standards for graduation as described in paragraph 1.

(2) Pass all graded leadership positions.

(3) Pass all peer reports.

(4) Lose no major item of equipment due to negligence.

(5) Have no outstanding unsatisfactory CIRs.

(6) Not be a turnback, other than for compassionate or medical reasons.

(7) Not have been retested in any skill evaluation.

b. The Distinguished Honor Graduate will be the officer and enlisted graduate with the best overall performance as determined by the academic review board.

c. In the event no student meets the criteria in 2 above, the student with the best overall performance will be designated Honor Graduate. There will be no Distinguished Honor Graduate.

d. An academic review board will be convened at the end of the Ranger Course to review the records of students who completed all the training but failed to meet course standards. This board will also consider and recommend the Distinguished Honor Graduate.

E. DISTINGUISHED HONOR GRADUATES

Since March 1956, the officer and enlisted man displaying the most outstanding performance in each Ranger Class have been designated as Distinguished Honor Graduates. At graduation exercises, they are presented with a Letter of Commendation, signed by the Commandant, USAIS, forwarded to each Distinguished Honor Graduate through his commanding officer and made a part of his official records.

F. REQUIRED UNIFORMS AND EQUIPMENT

1. Class A Uniforms: There are no Class A uniform requirements for personnel while attending the Ranger Course.

2. The following uniforms and equipment are minimum quantities required for all students.

NOTE: Those individuals assigned to units authorized to wear the Jungle Fatigues can wear them in lieu of the BDUs as indicated below:

Item	Quantity Winter	Quantity Summer
Boots, Combat Leather	2 pr	2 pr
Boots, Jungle (may be used in lieu of the combat boots during summer can be worn during the Florida Phase in winter)	0	2 pr
Belt, Black Web with Buckle	2	2
Coat, BDU	6	6
Cap, BDU	2	2
Drawers, Cotton underwear (optional)	7	7
Duffle Bag	1	1
Eyeglasses (military issue)	2 pr	2 pr
Eyeglasses, retainer band	2	2

Uniforms and equipment (Continued)

Item	Quantity Winter	Quantity Summer
Flashlight (military type)	1	1
Gloves, shell leather black (military)	2 pr	2 pr
ID Tags with breakaway chain	2	2
ID Card	1	1
Inserts, wool glove	2 pr	2 pr
Long underwear, wool, cotton, or polypropylene	2 pr	Ø
Name tape (last name)	2	2
Running shoes	1 pr	1 pr
Socks, black dress or polypropylene	3 pr	2 pr
Socks, wool, cushion sole	14 pr	14 pr
Socks, heavyweight (white)	4 pr	Ø
Sweatband, helmet liner	1	1
Sleeping shirt	1	1
Trousers, BDU	6	6
T-shirts, brown	7	7
Army Grey PT Uniform	1	1

NOTE: Individuals can bring and use any type of commercial undergarments (polypropylene, capalene, thermax) during the winter training period. If the color of these garments is other than Army OD or brown, the garment will not be visible when worn. Commercial insulated gloves and boots are NOT AUTHORIZED while attending the Ranger Course.

3. The following non-issue items are required (summer and winter):

Waterproof matches
Pocket size notebook
Pens
Pencils
Shoe shine kit, consisting of the following items:
    2 large cans of black or silicone shoe polish
    1 shoe brush
    1 large can of saddle soap
Extra bootlaces (5 pr)
Black tape, friction or electrical (2)
Batteries, D-Cell (4)
Combination padlocks (3)
Sewing kit (1)
Wristwatch (inexpensive but durable) (1)
Pocket knife (1)
Weapons cleaning kit, small arms (1)
Shower shoes (1 pr)

Non-issue items (Continued)

Waterproof bags (ziplock) (12)
Shaving and hygiene kit, consisting of the following items:
- 1 razor with blades and shaving cream
- 1 small mirror
- 1 soap dish and soap
- 1 toothbrush and toothpaste
- 4 large (brown) towels
- 2 small (brown) hand towels
- 2 cans of foot powder
- 1 chapstick
- 1 bottle of insect repellent

<u>NOTE</u>: Contact lenses are not authorized during the Ranger Course

4. The following optional items are highly recommended for Ranger students:

Map case
Map markers
Nylon cord (5-50 type)
Penlight with batteries
Plastic map protractor
Laundry soap (small box)
OD wool swe. o- (Army or USMC type)
Large trash bags
Extra small waterproof bags (ziplock)

5. Unauthorized items: Radios, tape recorders, cameras, civilian magazines, telephone sets, prewritten OPORD or OPORD annex formats, mountaineering equipment, <u>food items</u> not issued by RTB, vitamins, aspirin, over the counter drugs and any type of body supplements are unauthorized in each phase of training.

6. All uniforms will have all insignia removed except name tag and U.S. Army. Boots should be well broken in prior to beginning course. <u>Jungle boots</u> are not authorized during the winter in the Benning, Mountain or Desert phase of training, however they can be worn during the Florida phase.

7. All other required clothing and equipment will be issued by the Ranger training companies. It is not necessary for the student to purchase equipment on his own other than the items listed above unless he deems it necessary.

APPENDIX III

Recommendations of the Committee on Military Nutrition Research, National Academy of Sciences.

A Nutritional Assessment of U.S. Army Ranger Training Class 11/91

A Brief Report of

The Committee on Military Nutrition Research

Food and Nutrition Board

Institute of Medicine

National Academy of Sciences

to

Major General Richard T. Travis

Commanding General

U.S. Army Medical Research and Development Command

March 23, 1992

Produced under grant number DAMD17-92-J-2003 between the National Academy of Sciences and the U.S. Army Medical Research and Development Command

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine.

The Institute of Medicine was chartered in 1970 by the National Academy of Sciences to enlist distinguished members of the appropriate professions in the examination of policy matters pertaining to the health of the public. In this, the Institute acts under both the Academy's 1863 congressional charter responsibility to be an advisor to the federal government and its own initiative in identifying issues of medical care, research, and education. Dr. Kenneth Shine is President-designate of the Institute of Medicine.

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FOOD AND NUTRITION BOARD

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INTRODUCTION AND BACKGROUND

At the specific request of the COL Eldon W. Askew, Ph.D., Chief, Military Nutrition Division, U.S. Army Research Institute of Environmental Medicine (USARIEM) the Committee on Military Nutrition Research (CMNR) met in Washington, D.C. on February 5-7, 1992. COL Askew is the Grant Officer Representative of the U.S. Army Medical Research and Development Command (USAMRDC) for Grant no. DAMD17-92-J-2003 to the National Academy of Sciences for support of the Food and Nutrition Board's (FNB) Committee on Military Nutrition Research. The purpose of this meeting was to assist the Army in reviewing and evaluating the results of a research project conducted during the training program for U.S. Army Ranger Class 11/91.

Background Materials

Prior to assembling in Washington, the CMNR (the Committee) reviewed: 1) a background paper; 2) an information paper; 3) preliminary tables of results; and 4) a list of questions raised by the study. These background materials were provided by COL Askew. Copies of this information plus the meeting agenda, committee roster, lists of speakers and guests, and the data tables presented as slides or overheads during the meeting, are appended to this report.

Committee on Military Nutrition Research Meeting, February 5-7, 1992

On February 5, 1992 the CMNR convened at the National Academy of Sciences, Washington, D.C. Due to the nature of the research project, the Committee invited five advisors to attend the meeting to augment their expertise in the areas of energy metabolism, vitamin/mineral nutrition, immunology, and protein metabolism. In addition, a guest scientist who has conducted extensive studies of the Norwegian Ranger Training Program participated in the presentations and subsequent discussion. During the meeting the CMNR viewed a videotape of the Ranger Training Program, and heard a presentation of the goals of Ranger Training, presentations of the research results of the study: A Nutritional Assessment of Ranger Training Class 11/91, a report of the preliminary results of a study conducted by the Walter Reed Army Research Institute (WRAIR) at the Ranger School, and general commentary by the five guest advisors. The nutritional assessment study was conducted by the Military Nutrition Division, USARIEM, in response to a request from COL John J. Maher, III, Commander, Ranger Training Brigade. The CMNR was requested to review the results of the nutritional assessment study conducted by USARIEM and through their answers to the questions posed by COL Askew, make recommendations regarding the nutritional health and well being of Ranger trainees and future areas for research.

On February 6 and 7, 1992 the Committee and their guest advisors met in Executive Session and reviewed the research results in light of the goals and mission of the Ranger Training Program. The group discussed these materials at length jointly and then met in smaller groups to draft this report. After the Committee meeting, the Committee, their advisors, and staff worked together to review and revise subsequent drafts and components of this report. All CMNR members present at the meeting and their advisors have seen and approved the report. Subsequent to approval of the final draft by the Committee and their advisors, in accordance with National Research Council guidelines, this report was reviewed in confidence by a separate anonymous scientific review group. The Committee and advisors have reviewed the anonymous comments of this review panel and incorporated their suggestions where appropriate. Staff has then written a letter of response to the reviewers with the final report draft and obtained final approval of the report from the review panel. This report is thus a thoughtfully developed presentation that incorporates the scientific opinion of the CMNR, their advisors for this project, and the anonymous National Research Council reviewers.

Report Organization

Presented below is a listing of the questions posed to the Committee followed by a summary of the CMNR's recommendations. In the latter part of this report the Committee specifically address each of the questions posed by COL Askew and included with each answer is a general overview and specific recommendations. The report concludes with suggestions for areas where future research appears warranted. All materials used by the Committee in their deliberation process are included in the Appendices.

QUESTIONS POSED TO THE COMMITTEE

1. Is the change in the nutritional status of Ranger trainees of sufficient magnitude to compromise their health during Ranger training?

2. Are the changes in nutritional status noted transitory and not cause for undo medical concern, or are they severe enough to cause concern for the long-term physical health of the individual (post-Ranger Training)?

3. Are the immunological changes noted related to the plane of nutrition during Ranger Training or to other (eg. sleep deprivation) stressors?

4. Realizing that food restriction is an integral part of Ranger Training, can the nutritional status (risk) be improved significantly by relatively minor changes in the plane of nutrition?

5. Should Ranger trainees be furnished with multivitamin supplements?

SUMMARY OF SPECIFIC RECOMMENDATIONS

In answer to the questions posed above, the Committee deliberated and developed specific answers that are detailed in the sections below. Based on their deliberations a summary of the recommendations that arose from answers to the combined questions are as follows:

During Ranger Training

- establish a "food doctrine" to prevent excessive weight loss
- establish a maximum allowable body weight loss for Ranger Training consistent with Army guidelines
- review protocols for assuring the health of trainees during the entire training program
- consider modifications to apparel worn by Ranger trainees that will reduce dermal injuries and inflammation
- protocols need to be developed to document the occurrence, timing, severity, and etiology of clinical findings, such as overt infections, dermal injuries and inflammation, and problems related to climate, as well as prescriptions of all medication
- apply 1 of the 3 suggested modifications to the feeding program possible by immediately implementing the use of the Food Packet, Long Range Patrol (Improved) (LRP)
- develop a post-training refeeding and preventive health education presentation with and written materials for the guidance of training program participants

Short term follow-up

- expanded exit exam for all trainees
- physical exams at 3, 6, 9, and 12 months in the first year post-training that include physical, clinical and biochemical measurements
- during the first 6 months, careful attention to the residual capacities of the Rangers, especially personal motivation, history of infection and illness, weight gain and body composition, ventricular and diaphragmatic muscle function, hydration of lean tissue, and thermoregulatory capabilities

Long term follow-up

- expanded yearly physical exams if possible with a recorded history of major illnesses
- further prospective studies only if warranted
- conduct retrospective research study using existing data bases

A General Comment

There was an important question not posed to the CMNR. This question is:

What degree of stress through such stressors as food deprivation, sleep deprivation, extremes of environment and physical and mental performance tasks, under the watchful eyes of evaluators, is necessary to achieve the training objectives?

This question cannot be answered from the data presented and is one that is surely of concern to the Ranger Training Command. The data presented from the study are useful input to the decision process and can help answer questions about the impact of training on nutritional status, and short term medical and immune function concerns. Longer term evaluations can be achieved by both prospective and retrospective studies as suggested in the report. Obviously personal motivation of participants is an exceedingly important factor in completing the rigorous Ranger Training Program. Appropriate monitoring of individual trainees is needed to make certain that this high degree of motivation does not lead to excessive tolerance of conditions that need medical attention.

The Committee has no knowledge to what extent the attainment of training objectives is achieved. The CMNR encourages the Army to systematically evaluate all aspects of the Ranger Training Program and its components through follow up interviews conducted immediately after training and a number of years post-training. Such assessments, if not already in place, would provide direct information to the Training Program about the elements of the training experience that soldiers found were most beneficial to their later leadership abilities and performance in combat or during special operations.

REVIEW AND DISCUSSION OF QUESTIONS

In the following section the five questions posed to the Committee are specifically answered. After each answer the CMNR presents an overview of their reasoning and rationale as well as their recommendations as they relate to the question posed.

Question 1: Is the change in the nutritional status of Ranger trainees of sufficient magnitude to compromise their health during Ranger Training?

Answer: Yes. Based on a median body weight loss of 15.6%, documented infection rates that increased to 25.3% and 24.1% at the end of training (Phases III: Jungle and IV: Desert, respectively), and immune system markers, in the data as presented, there is indication that the health of Ranger trainees is at risk during the later phases of training. Trainee health may also be compromised for a period post-training.

Discussion and Recommendations:

The Committee notes that COL Maher should be complimented for his concern regarding the strenuous nature of the Ranger Training Program. The Committee also applauds the efforts of the USARIEM research group to study the issues involved in Ranger Training.

The Committee recognizes that Ranger Training is an important part of the military training needs of the Armed Forces. Further, that deprivation of food and sleep together with high levels of physical performance in extremes of environmental conditions are essential for the proper training outcome. Also it is recognized that such a program presents certain inherent health risks that must be balanced against the benefits derived from this training, such as awareness of the impact of nutritional deprivation on physical performance, morale and judgement. The strenuous nature of the training necessitates careful medical monitoring of participants. The Committee therefore suggests that there be a review of protocols for medical monitoring to assure the health of trainees during the entire training program. Such a review should take into account the current knowledge about risk of infection, heat stress, hypothermia, and other serious health complications that might be anticipated during training.

The Committee recognizes that while there has been a long history of success with the Ranger Program without obvious harm to participants, however there has not been a critical review of the longer term health effects on trainees after they complete or leave their training. Therefore, it is recommended that a short term follow-up study be conducted with a number of graduates of the program to assess the relative level of health problems in Ranger graduates compared to other military personnel. This follow-up study should take into account the type of initial assignment and the environment to which the individuals have been assigned as well as other factors that may have an impact on recovery and health.

Question 2: Are the changes in nutritional status noted transitory and not a cause for undue medical concern, or are they severe enough to cause concern for the long term physical health of the individual after Ranger Training?

Answer: The Committee was impressed by the scope and careful research design of the studies performed by USARIEM during Ranger Training - despite extremely difficult conditions. In particular, the CMNR recognizes the thoroughness of the research approach as exemplified by the effort and careful planning involved in movement and recalibration of the dual energy x-ray absorptiometry equipment to the field sites. However, these studies are not sufficient to provide definitive answers to the question of whether the future health of the Ranger trainee is affected. The health of each trainee would need to be examined in both the short term (weeks to months) as well as the long

term (years) following the completion of training. The Committee recommends that such studies be considered.

Discussion and Recommendations:

The short term considerations after such training involve the immediate ability of a Ranger to lead troops in combat and/or special operations. This individual may find himself under stressful conditions before there has been sufficient time or proper conditions to repair the losses which were incurred during the training conditions. Here it is important to consider not only the extreme loss of adipose tissue[1] and much smaller (but perhaps significant) loss of lean tissue, but the functional corollaries of such loss.

There is need for improved nutritional markers that examine the correlation between changes in body composition and loss of critical function. The loss of ability to function in a combat setting includes many things, from subtle loss of judgment to obvious weakness, fatigue, and loss of endurance. There is substantial evidence that loss of body protein stores is not confined to skeletal muscle alone, but is associated with a corresponding loss of ventricular, diaphragmatic, and intercostal muscles. The residual capacities of the Rangers at the end of training for both ventricular work and work of respiration needs to be examined. In addition, there is concern about the possible loss of specific protein and also the level of neurotransmittors derived from amino acids as related to brain function under such stressful conditions which may thus warrant further measurement.

In the short term it would also be important to examine the hydration of the lean tissue since it may vary more than predicted under severe field conditions and thus may influence the calculated changes in body composition. This could be approached by utilizing the data from the doubly labelled water to obtain total body water which could be compared with the dual energy x-ray absorptiometry (DEXA) data on body composition.

Finally from the short term perspective, much emphasis in the presentations was placed on the extremely high individual motivation that allowed many to finish (some to barely finish) the training course, and, that without this motivation, many of the successful candidates would not have completed the course. The Committee cautions that the aftereffects of such sustained motivation and performance during Ranger Training may be evidenced in variable functional performance and motivation over the ensuing days and weeks post-training. This aspect needs consideration and possible inclusion in future studies.

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[1]There was a change from an average of 14.6% body fat (Range: 5.7 - 26.1%, n = 55) at the beginning of training to an average of 5.8% body fat (Range: 4.4 - 11.9%, n = 55) at the end of training (see Appendix IVe.).

The possible long term health effects of such an extreme loss of body fat are largely unknown and are an important concern. B-mode imaging ultrasound, magnetic resonance imaging (MRI), and bioelectrical impedance techniques might be combined with DEXA to obtain further information on the changes that have occurred in muscle and fat and the distribution of the body fat which is regained post-training.

At present, there is not adequate information about changes in weight or metabolism during the first year post training. To monitor longer term health we propose that standardized physical examinations should be performed quarterly during the first year after training and subsequently at the regular six month intervals for several years if results from the first 12 months indicate such a prospective approach is warranted.

In addition, a central question of the Ranger Training Program relates to the functional significance of certain nutritional markers such as weight loss. The loss of immunocompetence with an increased incidence of clinical infections may represent important evidence of functional loss as a result of combined nutritional, environmental, and psychologic stress. The impact on the immune system of the high intensity physical activity coupled with under-nutrition deserves further exploration. Similarly, the impact on the sympathetic/adrenal system should be more rigorously ascertained, at least on an acute basis as indicated by recent reviews and commentary in this area (Chrouscs and Gold, 1992; Wellness Letter, March, 1992).

It remains to be demonstrated just what proportion of the decreased immunocompetence is specific to nutritional deprivation, however, it is also important to examine the problems associated with regulating body heat content in the light of nutritional deprivation. One of the speakers remarked: "Heat was the enemy early in the course and cold became the enemy toward the end of the course." This quotation referred to the variability in environmental temperature during the eight-week training period. For Ranger trainees, environmental temperatures may vary greatly depending on the Phase of training, hence training location in the desert, jungle, or mountains. In addition, the extremes of climate in these environments seasonally change dramatically and therefore the successive Ranger Training classes may experience widely varying external climates.

This quote is thus equally applicable to the problem faced by individual soldiers in regulating internal body temperature. "Cold as the enemy" at the end of Ranger Training was to be expected, in part, as a result of intermittent hyperthermia during heavy exercise and hypothermia secondary to cold exposure. However it has been shown that the thermogenic response to a mild cold challenge is progressively lost with weight loss in hospitalized patients. Furthermore, this thermoregulatory deficit with weight loss can be restored with nothing more than partial regain of body weight. Perhaps this functional loss of thermoregulation with progressive weight loss causes the vulnerability to hypothermia seen in the later weeks of Ranger Training.

The measurement of energy expenditure using doubly labelled water offers obvious advantages for field studies such as Ranger Training. However, certain assumptions are required for the use of this method, that usually include a stable food intake and hence a stable mid-range respiratory quotient (RQ) throughout the period of the study. Since this is undoubtedly not possible, special attention needs to be given to the need for periodic measurements of gas exchange or other approaches to the variations which might be expected in the RQ.

It would also be important to collect urine samples and estimate dietary protein intake for periods of two to three days during selected parts of the training. A knowledge of nitrogen excretion, even if only of urinary nitrogen, would be important in interpreting the weight loss and fat loss in each phase of training.

One particular aspect deserves comment. The observed small proportion of lean tissue loss versus the high proportion of fat loss, gave rise to repeated comments during the presentations that the results of the training were primarily those of an energy or a calorie deficit. This may be true only in an overall sense. For example, if one only uses data on the lean tissue present at the beginning and end of the training and thus calculates an average daily nitrogen loss, this average loss over time is seen to be relatively modest. However, the nitrogen excretion during certain selected periods of training may be much higher than the daily average. If this is true, brief periods of serious nitrogen loss might cripple fast-turnover proteins such as certain of the acute phase proteins and perhaps contribute to the growing vulnerability to infection reported in the second half of the training course. This supposition is of course, speculative but potentially relevant.

Question 3: Are the immunological changes noted related to the plane of nutrition during Ranger Training or to other (eg. sleep deprivation) stressors?

Answer: It is impossible to answer this question with the data now available - even though these data are extremely valuable and truly unique. Data emerging from the studies produced by USARIEM, by WRAIR and by Dr. Per Christian Opstad of Norway in the more rigorous but shorter deprivation studies on Rangers in that country, are not always consistent. Between-study differences may be due to differences in length of studies, in timing of sampling, degree of caloric restriction and sleep deprivation, and ambient temperature. The fact that climatic and other stresses involved during data gathering were not consistent must also be considered. Further, the methodologies of conducting certain tests, and of the analysis, presentation, and interpretation of data gathered by these three groups, were not always uniform.

Nevertheless, an overall consensus of the data certainly indicates the occurrence of numerous immunological compromises in the Ranger trainees. These involved T-cell and B-cell dysfunctions, and also those of phagocytic cells.

Discussion and Recommendations:

The T-cell deficits included variable reductions of delayed dermal hypersensitivity reactions and disturbances of in-vitro T-cell responses to mitogens. The B-cell deficits (undoubtedly in combination with altered T-cell and antigen-presenting cell functions) resulted in poor antibody responses in both primary and secondary exposure to vaccine antigens. Changes were noted in neutrophil performance of oxidative functions. Changes were noted in the numbers of the various circulating white blood cells. Cytokine measurements in both serum and cell culture fluids are still quite novel, but they too demonstrated changes that are undoubtedly meaningful, but presently, these cytokine data are difficult to interdigitate with other data for meaningful interpretation.

In regard to the immunologic profile examined however, there was no assessment of natural killer (NK) cell activity, nor assessment of the phenotype of important sub-populations of lymphocytes such as CD4, CD8, or CD3/CD56, which might be expected to be affected by the training. These assessments would have given considerably more insight into the effects on the immune system. NK activity has been shown in several studies to be particularly affected by stress (for example, Levy et al., 1991 a,b).

There were technical aspects of the processing of the samples that might have had an impact on the results. After collection, blood specimens were held at ambient temperatures for over 24 hours. It is quite likely that the measurements obtained were affected by such storage prior to separation of cells and plasma. Since environmental conditions varied substantially during training, the test results may have been affected by shifts in temperature and other parameters for which there was no apparent control. In addition, plasma cytokine assays are often difficult to control for quality under optimal conditions. The results of this project should be interpreted with caution due to the sample processing issues mentioned above. Further studies utilizing better control procedures for collection, separation and storage of samples would seem important.

It should be noted that the study conducted on Ranger Training Class 11/91 (Appendix IVh.) showed no significant reduction of delayed cutaneous hypersensitivity reactions, whereas the WRAIR study of Ranger Training Class 12/91 (Appendix IVk.) pointed to a depression in such reactivity. It is difficult to compare the results directly since there was less specific data provided at this time from the WRAIR project. After the scientists involved have had the opportunity to more fully analyze the data from both projects (for example, see below), joint discussion of the results would be informative.

It is also difficult to adequately assess the changes that appear to have occurred with regard to the in vitro testing. Analyses performed were entirely based on pooling data for each time point, rather than using each individual as his own control and utilizing alternative statistical analyses. It is recognized that the presentation to the CMNR was based on preliminary data analysis by the scientific teams. As the analysis

of this data progresses with the addition of standard deviations and more extensive statistical procedures, the results will be more readily interpreted.

Over 50 percent of the Rangers developed infections requiring antibiotic treatment during the USARIEM study. These infections primarily involved the lower extremity, and included cellulitis of the knees, legs, and feet. In view of the significant number of infections of the lower extremities, special attention should be directed to reducing stress on the legs and feet. Examination of procedures for proper design and fitting of the Ranger boot is suggested. A numbing sensation in the toes has long been a recognized problem among soldiers. Limited more specific data on digitalgia paresthetica of the toes (numbing of the toes) from an Israeli Defense Forces study indicated that this condition was a neuropraxia related to soldiers adaptation to marching with heavy packs (see Appendix IVm.). The CMNR thus suggests that Ranger boot fitting be done in such a manner that gait accommodation to carrying heavy loads is considered. In addition, since many of the abrasions that may subsequently lead to infection apparently occur in the knee area, special padding of the uniform such as knee pads that can be inserted in the uniform may be appropriate. Knee pads that are strapped on over the pant legs are often uncomfortable, more cumbersome, and hence less likely to be used by the soldier.

In addition, respiratory tract infections were prevalent; the *S.pneumonia* carrier rate was unusually high in this study despite bicillin prophylaxis. The several respiratory infections were not adequately characterized in the information provided to the Committee with regard to etiology. It is quite possible that a substantial proportion of these were viral in nature, particularly since other clinical studies have indicated that difficulties in handling stress may be associated with increased frequency and morbidity from viral respiratory infections, concomitant with depressed NK activity (Levy et al., 1991 a,b). Gastro-intestinal infections have also caused problems in other Ranger Training classes. However, it is currently impossible to identify the exact cause of these clearly identified impairments in immunological functions and host resistance, i.e. to assign blame to the nutritional losses versus the stress (or any one of the many stresses being experienced).

Training-imposed dietary restrictions certainly contributed to losses of body weight and nutrient stores. Arduous physical activity certainly contributed to increased metabolic demands and high rates of nutrient expenditures. The complex and interacting physical and emotional stresses certainly altered the hormonal milieu of the body in these trainees, with multiple secondary metabolic consequences. And of especially great importance, the extreme physical exertion, the multiple minor injuries and inflammatory responses, and the intercurrent infections could each (alone or in combination) have triggered acute-phase reactions and cytokine releases.

Acute phase responses, if triggered by the endogenous release of the cytokines IL-1, IL-6, and TNF [cachectin], could result in hypermetabolism, accelerated catabolism

of somatic body proteins, hormonal changes, extensive metabolic changes in hepatic cells, and a wide variety of nutrient losses. The type of cachexia produced by the acute phase response could lead to immunological dysfunctions. Cytokine initiated cachexia is hypothesized to be a more important cause of nutritionally-induced immune system dysfunctions than simple uncomplicated starvation in adults. The available USARIEM data suggest (but do not prove) that acute phase responses were occurring during the Fort Benning Phase of the Ranger Training Program.

Occurrence of acute phase responses early in the Fort Benning Phase of the USARIEM study is suggested by early changes in iron-related data. These include the fall in serum iron values, the increase in unsaturation in serum iron binding capacity, and the increase in serum ferritin values. These changes are all indicative of an IL-1 induced movement of iron from plasma for temporary sequestration in tissue storage sites. An increase in BUN also suggests an increased protein-catabolic response (which would not be observed in uncomplicated starvation), as does the previously discussed hormonal data.

Additional data to confirm the occurrence (or absence) of an acute phase reaction during Ranger Training would be desirable in future studies. Such data should be gathered with appropriate timing to detect possible abrupt declines in plasma zinc values (as well as those of iron), abrupt declines in plasma free amino acid (especially glutamine) values a slower increase in serum copper values, and an increase in plasma concentrations of the acute-phase reacting plasma proteins, such as haptoglobin, C-reactive protein, orosomucoid, and ceruloplasmin, as examples.

Committee discussions emphasized the need for measurements of circulating free glutamine concentrations. This would provide an important index of the relative depletion of this specific amino acid as a consequence of a catabolic response involving the breakdown of body protein, especially muscle protein.

Additionally, and of special importance to the immunological questions at hand, is the growing body of reports that adequate glutamine availability is essential for normal immune system function. Current data suggests that glutamine repletion reduces microbial colonization and the incidence of infection in immunocompromized catabolic patients.

However, a combination of cytokine-related catabolic stress coupled with diet-induced protein-energy malnutrition consistently leads to a synergistic combination in which immune system functions and other host defense measures are severely compromised, and secondary infections are common.

The magnitude of food deprivation in the trainees is well documented by excellent measurements of body composition and anthropometric findings as well as by losses of body weight. The extreme hunger experienced by the trainees constituted an important

emotional stress – severe enough to cause some of them to violate honor code requirements. However, available immunological data and increased infection rates cannot, at this time, be ascribed solely to nutritional deprivation. Historical evidence shows that severe starvation alone (in the absence of other stresses or catabolic illnesses) may not be rapidly detrimental to immune functions, and may not lead to an increased susceptibility to infectious illnesses.

Multiple concomitant stresses (purposely imposed on the trainees, and probably necessary for the military success of the program) include food and sleep deprivation, arduous, prolonged, and at times, dangerous training requirements, and the self-imposed drive to succeed. These stresses cannot be differentiated by any currently known hormonal or psychological profile. The presence of such stresses is reflected by the newly available hormonal data, including those defining changes in serum cortisol, testosterone, and insulin-like growth factor I values. Further, it is impossible to determine if these stress-compatible hormonal changes were due solely to some single observed stress (i.e., sleep deprivation, hunger, the other physical and emotional variables, alone or in combination), or if they were concomitant aspects of an acute phase response, or even of protein-calorie malnutrition. More consideration should thus be placed on the likely influence of psychological stress and the perception of all aspects of the stress by the trainees. Other studies of the effects of stress on the immune system have indicated the importance of the perception of stress and the ability of the individual to handle stressful situations. This might be quite heterogeneous among the trainees. Personality and psychological assessments of stress and its effects on psychometric parameters should thus be seriously considered for future studies.

In regard to attempts to sort out the effects of various variables on the immunologic parameters, it is worth mentioning that the Office of Naval Research has recently been performing detailed studies of the psychological effects of regular basic training of naval recruits on the immune system. This type of training, although quite less rigorous and physically stressful, has been associated with multiple changes in immunologic function. Insight into such comparative data seems pertinent to the studies of the Rangers. This is also related to plasma beta endorphin which has been shown to correlate with stress-related alterations in NK activity.

Further research during Ranger Training should, ideally, include prospective, controlled studies which will identify the occurrence, duration, and severity of acute phase reactions, should they occur. Data should include several biological indicators of the acute phase reactions, as well as measurements of key cytokines and their receptors. Investigative priorities should be clearly established, however, since all studies and additional data mentioned in this section cannot be accomplished and still meet the goals of Ranger Training.

Immunological studies, including responses to primary and secondary immunization, should be repeated in additional trainee groups. This will broaden the

immunologic data base, and help to certify its consistency, since different Ranger classes experience different climatic and other stresses during their training cycle.

A standardized protocol involving adequate medical observations is needed to document the occurrence, timing, severity, and etiology of clinically evident infections, and to correlate with immunologic and nutritional findings.

The data on vitamin and mineral nutrition already obtained is excellent and does not need to be repeated. Information on possible changes in Vitamin E, zinc, copper, and selenium must still be gathered.

Other nutritional data, including effects of the training and associated stresses on protein and amino acid (including glutamine) metabolism, would be helpful. This would be even more important if future studies permitted increased feedings during brief periods between training phases. Naturally, all these data should include adequate pre- and post-training controls.

Previous prophylactic antibiotic use has been authorized. Additional preventive measures should be considered to avoid inflammatory skin lesions, such as padding sewn into uniforms to protect knees, as previously described, and also for pressure point areas of packs and equipment. Drug prophylaxis should be considered to block prostaglandin-related components of the acute phase reaction.

Ranger Training does introduce many biologically important variables concomitantly, or in rapid succession. We are therefore dealing with a multifactorial problem, one in which the individual components may never be fully differentiated. While additional research data will be most useful, present steps to avoid or minimize the immunology-related medical problems encountered during Ranger Training include:

- nutritional augmentation compatible with training requirements (these may include increased intake of calories and/or protein);
- improvements in military uniforms to reduce dermal injuries and inflammation, in particular, better fitting boots to reduce toe numbness and risk of foot infection and possibly adding foam insert pads to the knee area of trousers used during training;
- better surveillance of infection incidence;
- judicious use of prophylactic measures to prevent infections; and
- possible use of prophylactic agents (i.e., ibuprofen, aspirin) in doses sufficient to minimize prostaglandin-related components of the acute phase reaction without masking symptoms of a developing infection.

Question 4: Realizing that food restriction is an integral part of Ranger Training, can the nutritional status (risk) be improved significantly by relatively minor changes in the plane of nutrition?

Answer: Yes. The charge to the Committee is to recommend alterations in nutrition that might result in a reduction in attrition and decrease nutritional risk. The Committee recommends that this be accomplished by establishing a "food doctrine".

Discussion and Recommendations:

Critical to answering this question are the two major principles of Ranger Training:

- Deprive the soldier of sleep and food while pushing him to the maximum of his endurance. The purpose of this exercise is to show future leaders at what point they reach their limit of effective function, and conversely, at what point their men would predictably reach their limit of effective function.

- Creating and maintaining periods of hunger is of critical importance to achieving the desired level of multi-faceted stress on the soldier.

An important aspect of the data presented by the Walter Reed Army Institute of Research (WRAIR) study (Appendix IVk.) was that soldiers on field training exercises (FTX) who were given two Meals-Ready to Eat (MREs) per day did not experience the cognitive dysfunction characteristic of the USARIEM study. This suggests the possibility that one of the two major principles of Ranger Training would not be realized with sufficient feeding. Thus the CMNR recommends that, instead of increasing total food intake, a more specific "food doctrine" be adopted. Just as the Army has a "water doctrine", a "food doctrine" can be viewed as important for optimal performance. Such a food doctrine could be incorporated into the Ranger School Operations. This would include the provision and consumption of adequate energy intake for optimal performance at times when food is available. It would be put into practice by providing guidelines for acceptable body weight loss during non-field operations and include maximizing food intake whenever possible during field operations. There is no set allowable body weight loss for prolonged field exercise according to U.S. Army policy, however 3% body weight loss is often used as a guideline. For Ranger Training, the Committee recommends that the Army establish a specific target for maximum percent body weight loss. This target would be based on the results of the present study and future research on the effects of the degree of weight loss on physical and cognitive performance and immunocompetence. The CMNR suggests a preliminary estimate of this target might be in the range of 10-12% body weight loss overall.

In addition to the implementation of a food doctrine, the Committee recommends review of the following three potential scenarios for altering the current feeding status

of soldiers undergoing Ranger Training. It is expected that these approaches would result in better nutrition and reduction in attrition rate:

- Match intake and output. Increase food intake to match energy expenditure during the non-FTX phases of training (part of the "food doctrine"). Continue to feed troops one MRE during the FTX training; this is likely to produce the desirable degree of deprivation during the later phases of training. It is possible that approach may not provide the appropriate deprivation early in the Fort Benning phase.

- Short bursts of deprivation. If greater deprivation is desired, it would be preferable to provide the deprivation in isolated periods of time, followed by periods of greater intake after periods of FTX training (part of the "food doctrine"). Such a scenario should result in less suppression of the immune function. It would be accomplished by further reduction of Intake during FTX, perhaps by altering one day of starvation followed by a day of feeding one MRE, for a total period that would last only about 7-8 days. Dr. Opstad has demonstrated that Norwegian Rangers can develop cognitive dysfunction within five days if they are almost completely deprived of food and sleep. The excess feeding following the FTX period would be of special importance to restore immune function and body weight more rapidly.

- Slightly increase intake yet still have deficit. Increase food intake during FTX training either by a moderate increase of 200-300 kcal/day such as by using the new Food Packet, Long Range Patrol (Improved) (LRP)[2] that provides a minimum of 50 grams protein and 1500 kcal or by providing two MREs per day. This level of feeding apparently was implemented during the study conducted by WRAIR that, based on preliminary data presented, indicated a decreased attrition rate compared with previous classes.

Regardless of which alteration might be selected, given the levels of depletion in body weight and immune function in the USARIEM study, the CMNR is concerned about the health status of the individual soldier after completion of Ranger Training. Additional steps must be taken to ensure that the soldier is aware of the types of foods and weight gain that should follow the period of deprivation upon leaving training. It is the understanding of the Committee that the soldier is returned to his unit, which may actually, depending on timing, be in a deployment mode. Thus the opportunity for the soldier to regain lost body weight and immune function may be compromised if the

[2] The Food Packet, Long Range Patrol (Improved) (LRP) is the new name for the USARIEM research and development product: the Long Life Ration Packet (LLRP) that was reviewed by the Committee on Military Nutrition Research in 1991 (Publication IOM-91-03, Institute of Medicine, National Academy of Sciences). Information on the menu components and estimated nutrient content are included in Appendix IVI.

following tour of duty is in an arena in which [illegible]us and increased energy expenditure will predominate. Thus it is [illegible] that the Ranger Training Program include information on specific methods [illegible] body weight, lean body mass, and health status following completion of the training. Such nutrition education would include information on components in the various types of military rations and which components are critical to achieving the objectives of regaining body weight and health as quickly as possible.

Question 5: Should Ranger trainees be furnished with multivitamin supplements?

Answer: No, based on current data, significant benefits from the use of vitamin and mineral supplements would not be expected. However, future research may suggest the need for more specific supplementation and routine assessment of the vitamin/mineral status of trainees pre- and post-training through scheduled health exams should be considered.

Discussion and Recommendations:

The Committee recognizes the importance of essential vitamins and minerals in maintaining good nutritional status. The Military Recommended Dietary Allowances (MRDAs) assure that military rations contain the recommended quantities of these micronutrients in the foods consumed by the soldier. Based on this, personnel entering the Ranger Training Program are in good nutritional status. During the non-FTX periods the participants receive adequate food resulting in adequate intake of the micronutrients. When in the FTX phase of the training, participants receive one MRE furnishing 1300 kcal and at least 1/3 of the MRDA for micronutrients. During this time energy expenditure is dramatically increased.

Analysis of indicators for vitamin and iron status provides no evidence of any impairment of any biochemical indicators of nutritional status for these nutrients. This is not surprising because the subjects entered the program with adequate reserves. One would not expect deficiencies to occur in the short time of one week.

A transitory decline of serum iron concentrations after the baseline period was considered a stress response. This was further discussed in the earlier section on immune function. It is considered a result, not a cause of the acute phase reaction.

While zinc analysis was not reported for the participants, the central role of this element in immune functions is well recognized. During discussions it was reported that a preliminary analysis of four subjects did not indicate a decline in zinc status at the end of the training. We would not expect that zinc status would decline significantly during one week of food restriction because of compensatory increases of zinc absorption during reduced intakes and because participants were consuming at least 1/3 of the MRDA even during food restriction, however more data are needed to confirm this hypothesis.

Several other trace elements (i.e. copper, selenium) are also known to participate in immune reactions. The status of those elements was not measured. Marked deficiencies would not be expected to develop in the short period of time of reduced intake, however these could be measure instead of vitamins in subsequent studies.

AREAS FOR FUTURE RESEARCH

The USARIEM study provided much valuable data but also raised a number of important questions where more research is needed. Among questions raised are the following:

1) What are the relative effects of food deprivation and sleep deprivation on compromised immune function and inability to complete the course?

2) Are there any <u>short term</u> consequences (< 12 months) of Ranger Training on health status, body composition, and physical performance of Ranger trainees?

3) Are there any <u>long term</u> consequences (> 12 months up to 25 years) of Ranger Training on health status and body composition of Ranger trainees?

Intervention Study

To answer the first question, ideally, a 2-way factorial design in a single training class would be run. Treatment groups would be 1) adequate sleep, adequate food; 2) adequate sleep, food deprived; 3) sleep deprived, adequate food; and 4) sleep deprived, food deprived. Main effects (sleep, food) and interactions would be statistically evaluated with a 2-way Analysis of Variance (ANOVA).

However, the opinion of the CMNR is that it would not be feasible to conduct such a study in a training environment without compromising the training mission. We instead believe that the food issue should be investigated first, as described below. It is possible that at a subsequent time it may be desirable to examine the issue of the effects of sleep deprivation stress on immune function and success rate.

In a future class at Fort Benning volunteers could be randomly assigned to two groups: 1) less food; and 2) more food. The group given less food would follow the food protocol of the just completed Ranger study. The group provided more food would be allowed full access to food during the short periods between the field exercises and in the initial phase at Fort Benning. In the field exercises these trainees would be provided with two rather than one MRE per day. The data collected in this study would be essentially the same as that collected in the just completed Ranger study. Less emphasis could be placed on indicators of vitamin status and more on indication of immune function, selected minerals, hormonal status, protein metabolism, and body

composition as indicated in the earlier sections of this report (see questions 2 and 3 above), as well as follow-up studies of Ranger trainees who were and were not successful in completing the course.

The CMNR recognizes that important logistical and morale issues are raised by differential treatment of trainees. If it is not possible to carry out a study as described above, we suggest that the study just completed be repeated at the same time of year, but that more food is supplied as described above. This design is much weaker and the results will be much less conclusive because the sequence of field exercises would be different, the weather and other environmental factors would be uncontrolled, as would be the variable presence of infectious disease. It is possible that some of the questions posed by Ranger Training may be addressed through carefully designed studies in more controlled experimental conditions using the environmental chambers at USARIEM.

It is suggested that any future evaluation projects include a systematic collection of data on mental performance. The addition of structured interviews in which probing questions are asked to further assess cognitive performance, would provide useful information. This could be done within the current training protocols. Comparison could be made with soldiers not undergoing sleep and food deprivation, but assigned to the same tasks.

Short Term Follow-up

From the results of the USARIEM study it seemed clear that graduates of Ranger Training were in a depleted nutritional and health status. The Committee believes it is important to follow-up the graduates in the first year immediately following graduation. At three, six, nine, and twelve months following completion of the course, a complete physical examination should be given, including clinical and biochemical measurements. The blood work should include assessment of immune function and hormonal status. Body composition and physical performance should also be assessed.

Long-Term Follow-up

If analysis of data collected from short term studies of Ranger Training classes indicate a need for further follow-up, consideration should be given to a longer term study of several years duration.

Retrospective Study

To address long term effects of Ranger Training in a cost effective manner, it would also be desirable to carry out an epidemiological retrospective study in which all graduates of Ranger Training for the last 25 years are compared with matched controls who did not participate in Ranger Training. The needed data could be obtained from the medical records and other military data bases that are already in use for

retrospective studies of this nature. The questions to be asked would be how the groups compared in mortality, morbidity, body composition, physical performance, and overall health status. The control group would need to be carefully matched for as many variables as possible other than undergoing Ranger Training. This study could potentially identify the presence of any major, long-term health risk factors associated with Ranger Training.

CONCLUSION

In conclusion the CMNR and their advisors found the questions raised by the Ranger nutritional assessment project to be of great importance. Further studies offer both improved conduct of Ranger Training and may also be of more general clinical importance for the care of injured and critically ill patients. The Committee on Military Nutrition Research is pleased to provide these recommendations as part of its ongoing activities in assisting the Military Nutrition Division of USARIEM.

References

Anon. (1992). Does exercise boost immunity? *U.C. Berkeley Wellness Letter*. March:6.

Chrousos, G.P. and Gold, P.W. (1992). The concept of stress and stress system disorders. *JAMA*. 257:1244-1252.

Levy, S.M., Fernstrom, J., Herberman, R.B., Whiteside, T.L., Lee, J., Ward, M., and Massoudi, M. (1991). Persistently low natural killer cell activity and circulating levels of plasma beta endorphin: risk factors for infectious disease. *Life Sci*. 43:107-116.

Levy, S.M., Herberman, R.B., Lee, J., Whiteside, T.L., Beadle, M., Heiden, L., and Simons, A. (1991). Persistently low natural killer cell activity, age, and environmental stress as predictors of infectious morbidity. *Nat Immun Cell Growth Reg*. 10:289-307.

APPENDIX IV

Follow-up Study of Rangers studied in Class 91-11.

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INTRODUCTION

Following the analysis of data obtained from Ranger Class 91-11 and the prompt response of the Ranger school to increase the caloric intake of student, it was decided to obtain followup information on the soldiers who had been studied. Because of the increased ration schedule in subsequent classes, this group represented a onetime opportunity to study recovery in a worst case energy deficit scenario. It was also important to define the state of recovery by 6-months post-training and to obtain recall data on the types of problems encountered and of subjective impressions of the time course to recovery in order to generally define the framework for a more detailed follow-up study in a second (follow-on) Ranger study in Ranger class 92-11. This short-term followup was also recommended by the Committee on Military Nutrition Research of the National Academy of Sciences (Appendix I) and directed by MG Travis, Commander, US Army Medical Research & Development Command. The followup study was approved as an addendum to the original Ranger protocol and was endorsed by the Commander of the Ranger Training Brigade, COL Maher (Figure 1).

METHODS

Of the 55 finishers from the main study, 24 were active Army subjects, located within CONUS (or Alaska and Hawaii), who could be reached by phone and were thought to be available for the followup study, pending unit commander approval. A letter of invitation and instructions, along with a fund citation for TDY travel, was sent to each of these 24 individuals. Eight soldiers arrived for the followup study. The other 16 were deployed in field training exercises (10 soldiers) or placed on alert status (3 soldiers) at the time of the study (4-6 May 1992); 3 could not be released by their units for other reasons.

The soldiers who participated in this study came from Ranger units (3), Special Forces units (2), LRSD units (1), or other Infantry units (2). Three had entered Class 91-11 after waiting 30 days at Fort Benning ("gulag") for class openings. Although all of these soldiers were studied at the end of Ranger training in class 91-11, six of the eight had recycled the final 2 week phase after the original study before successfully completing the requirements for the tab. One soldier was returning after having been medically dropped for an orthopedic injury one year before.

ATSH-RB (40-400v) 16 April 1992

MEMORANDUM FOR COMMANDERS, RANGER TRAINING BATTALIONS

SUBJECT: Followup Study of Soldiers from Ranger Class 11-91

1. The rugged nature of Ranger training, and the historical records of high medical attrition (approximately 600 medical drops per year) justify small changes in Ranger training to make it an even better, yet safer, program. Given that the course content has been revised and the length of the course expanded over the past several years, one of my initial concerns upon assuming command, was that the amount of weight loss in soldiers going through Ranger training had become too severe, possibly, affecting both current and future performance and conditioning/recovery.

2. To gain more information in this area, I invited the U.S. Army Research Institute of Environmental Medicine (USARIEM) to conduct a study of Class 11-91 last summer. As a consequence of the information obtained from this study, we have made changes in Ranger training which make it an equally challenging but a safer program. With a very short lead time, USAREIM has now been tasked to perform a 6-month post training followup of these same soldiers to determine what longer term consequences may exist and to develop an informational program for soldiers completing Ranger training.

3. I know that all of you have a lot on your plate, and this is another short notice task, but your help is needed to complete this important effort. I ask that you favorably consider the release of the study participants currently in your command to participate in this followup study, if it does not conflict with the soldier's scheduled leave or with any essential training. Furthermore, this is a research study for which participation is voluntary, with the guarantee that there will be no adverse consequences to a soldier who chooses not to participate. USARIEM is requesting your soldier(s) for three days of testing, 4-6 May 1992 (enclosures) at their location near Boston, Massachusetts, and they will provide the TDY fund cite.

4. If you have any questions concerning this study, you may address them to the study project officer at USARIEM, MAJ Karl Friedl, at DSN 256-4875 or to COL E. Wayne Askew, DSN 256-4874. Your assistance is appreciated.

John J. Maher

Encls
as

JOHN J. MAHER III
Colonel, Infantry
Commanding

Figure 1. Letter of endorsement from the Commander, Ranger Training Brigade.

Each volunteer was given a detailed questionnaire about their eating habits and other factors related to return to pre-Ranger training fitness and habits. Each soldier was then interviewed by a nutrition expert (K.H. or D.J.) about their questionnaire responses to obtain missing information or to followup on additional information as patterns of post-Ranger nutritional habits emerged.

A detailed medical records review was performed along with a complete physical examination of each soldier (LTC Lester Martinez-Lopez, M.D.). The incremental lift test was performed, exactly as it was performed in the main study and by the same observers (Mr. Peter Frykman & SGT Michael Johnson). Body composition was tested in exactly the same way in which it was performed in the main study, by the same observer (Mr. Robert Petrin, anthropometry) and with one of the same DEXA devices, by an experienced technician (SPC Sherryl Kubel).

A fasted blood sample was also drawn at 0800 h, after the second night following arrival at Natick. Clinical chemistries, hematocrit, hemoglobin, and testosterone (as a stress marker) were measured in these samples.

RESULTS & DISCUSSION

The physical examinations and clinical chemistries revealed that these 8 soldiers were all in excellent health. Cholesterol levels had returned to normal levels (average: 152±23 mg/dL)(Figure 2). Erythrocyte and serum markers of vitamin status and other nutritional and metabolic indicators fell within the normal range for 6 of the volunteers. Levels of all measured vitamins and ferritin were elevated to or above the upper limit of the normal range in a seventh volunteer who used a range of nutritional supplements; his cholesterol was well below average (113 mg/dL). The eighth volunteer, who smoked heavily and acknowledged poor current fitness and eating habits during the dietary interviews, demonstrated values at the opposite extreme, with a deficiency of Vitamins B_6, B_{12}, C and an elevated ferritin and iron, although liver function tests and other health indices were completely normal. Serum testosterone levels which had consistently decreased in response to the stress of Ranger training were fully restored to normal levels.

Five of the eight soldiers had encountered toe numbness which persisted for 1-3 months after the end of training, although one soldier still had some toe numbness

on one foot (the only one who had not worn jungle boots and wool socks; he wore leather boots with a nylon/wool sock combination). One soldier had scars over the sacral region from rucksack abrasions which occurred during Ranger training. Five soldiers had infections during Ranger training but had no residual complaints at the time of followup. Seven of the 8 soldiers experienced diarrhea for 3 days to 2 weeks after the end of training and 5/8 encountered sleep problems for approximately 1 month post-training. Since training, 1 soldier had separated his right shoulder but was fully recovered; 1 fractured his left ankle and had a reduced range of motion in the joint; 1 had an overuse injury with calf swelling which had resulted in a 10 day convalescent leave and was resolved.

The physical measurements had all returned to pre-training levels. Representative data is shown in Figure 3 (body weight & % body fat), Figure 4 (abdominal circumference and suprailiac skinfold), and Figure 5 (fat-free mass & incremental lift performance). These results indicate that by 6 months post-training, the physical parameters were completely returned to normal.

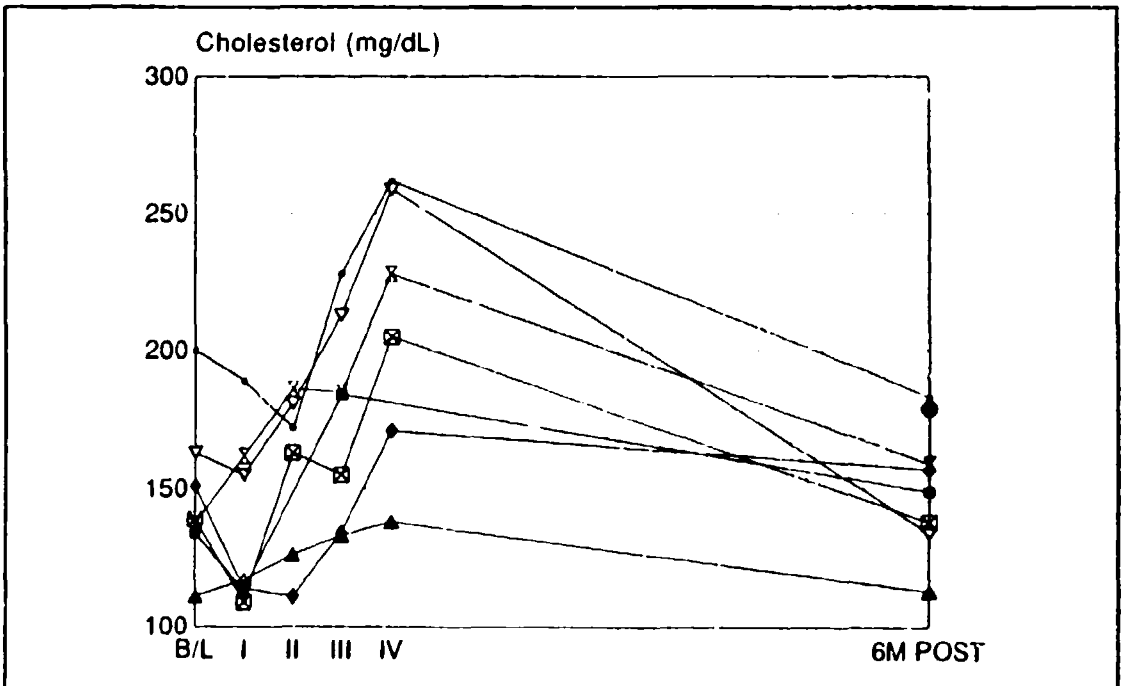


Figure 2. Serum cholesterol levels (following overnight fasting) measured at the beginning and end of each phase of Ranger class 11-91, and 6 months later.

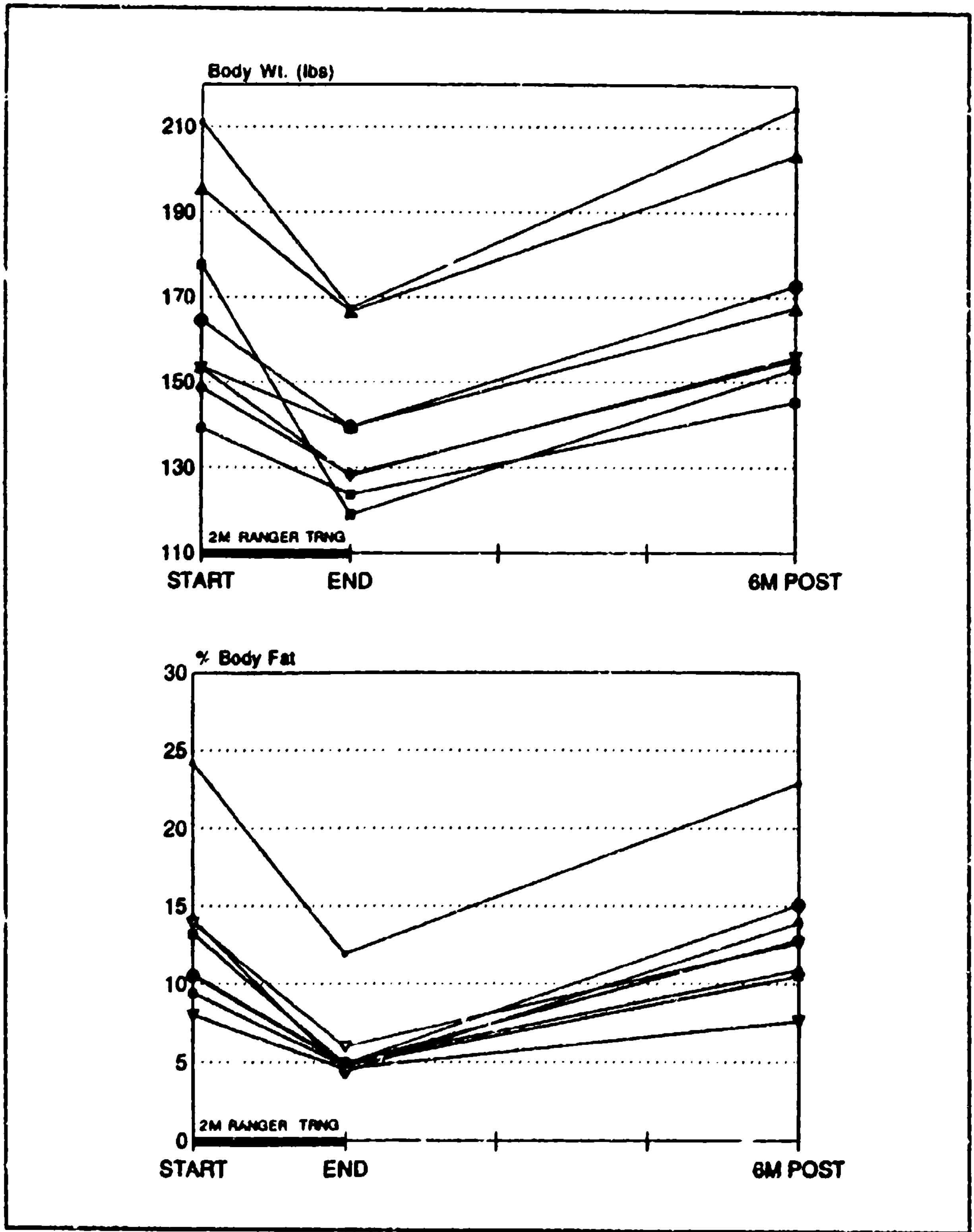


Figure 3. Body weight (upper graph) and percent body fat (lower graph) measured at the beginning and end of Ranger class 11-91 and 6 months later.

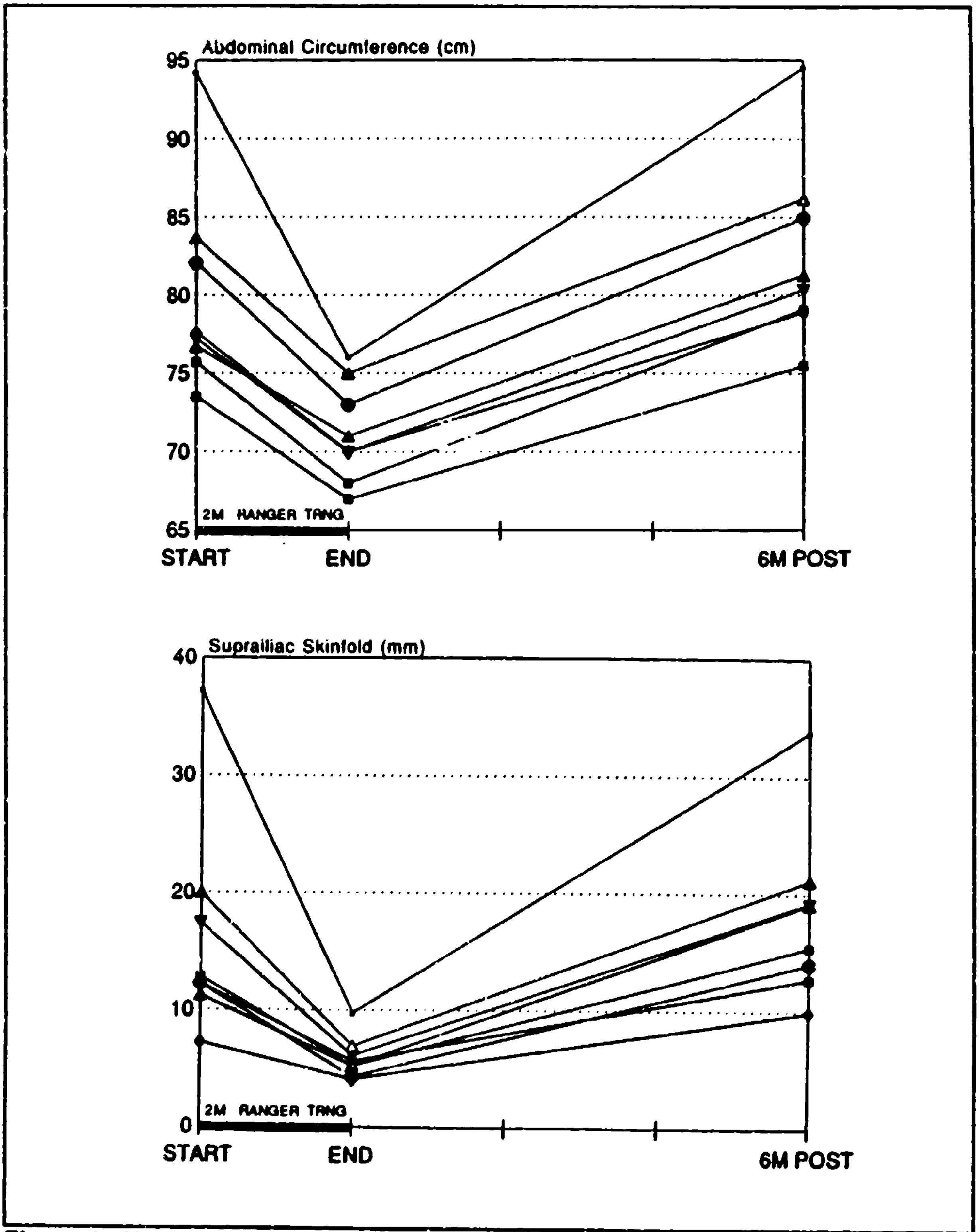
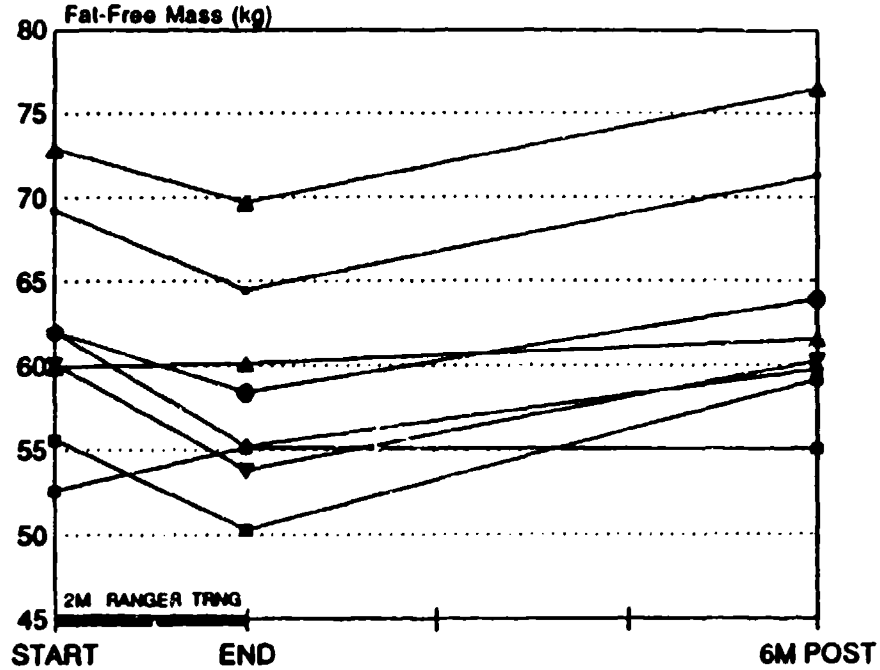


Figure 4. Abdominal circumference (upper graph) and suprailiac skinfold thickness (lower graph) measured at the beginning and end of Ranger class 11-91 and 6 months later.



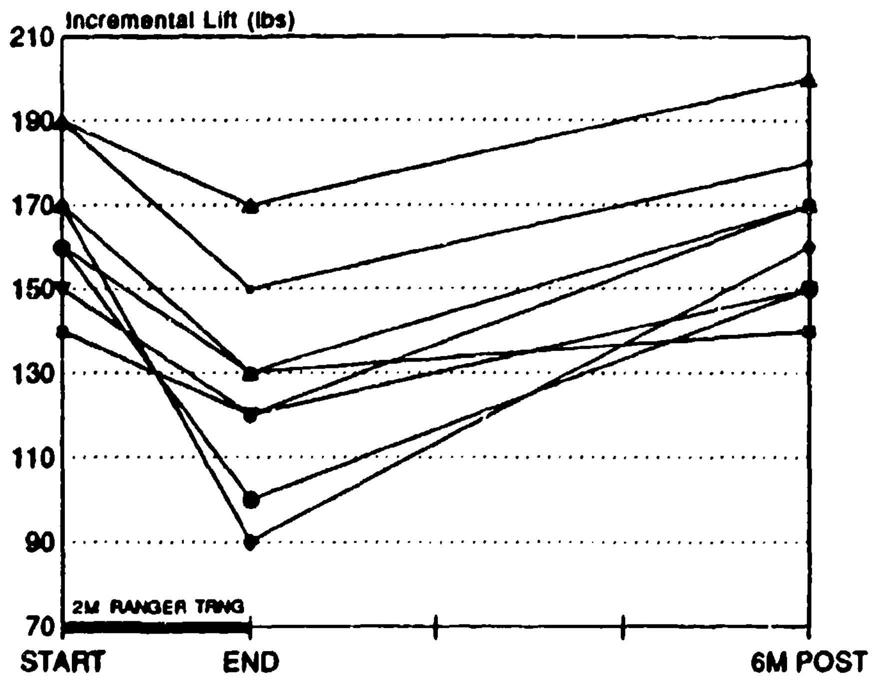


Figure 5. Fat-free mass (upper graph) and incremental lift performance (lower graph) measured at the beginning and end of Ranger class 11-91 and 6 months later.

The results of the questionnaires and interviews are as follows.

Personal priorities - 1st day post-Ranger training. When asked to rank the 5 most important things to do on the first day after Ranger school, 7/8 put eating in first place and 6/8 put sleeping in second place.

Food intakes. Overeating was common to all of the soldiers in the followup study and this appeared to be closely associated with diarrhea, cramping, and nausea. After 3-7 days, the Rangers reestablished control of their food intake (Table 1).

Food cravings. Four of the soldiers stated that they did not return to normal food types and amounts until 1 month after Ranger school, the others all took longer. Food consumption increased over pre-Ranger levels in the first month after training with increased consumption of these foods:

1.	(7/8)	doughnuts, cookies, cakes, pastries
2.	(6/8)	ice cream beverages
3.	(5/8)	beef (hamburger, steak), pork salty snacks (chips, peanuts)
4.	(4/8)	fried foods
5.	(3/8)	chocolate, candy breads
6.	(2/8)	fruits, vegetables

Thus, the primary increase in consumption was for foods which are high in fats and sugars. Specific individual cravings were for peanut butter, pizza, and chocolate. Table 2 summarizes some specific individual comments.

Eating out. The soldiers indicated that they had increased their eating in fast food resturants by > 5 times/week (6/8); most meals were ordinarily eaten at home, with only 2 eating in an Army dining facility and 1 soldier eating primarily in resturants.

Vitamin supplements. One Ranger had used a multivitamin throughout Ranger school and continued to use it. Two used a multivitamin occasionally during training. Seven of the 8 soldiers were not using any vitamin supplements after Ranger school.

Table 1. Individual descriptions of food intake and gastrointestinal complaints.

Ranger A did not try to control his food intake until the month after Ranger school. He suffered no gastrointestinal problems.

Ranger B reported eating until he couldn't eat another bite. His "brain kept telling him to eat." He took Tums for indigestion for 2 weeks during the Desert phase layover (awaiting class 12-91). He experienced nausea twice/day for the first 3 days and diarrhea 8 times/day for 14 days during this layover, and for several days again after graduating with class 12-91.

Ranger C did not try to control his food intake; he ate constantly and always had a candy bar in his pocket. He had diarrhea and cramping 4 times/day for 3 weeks during the Desert phase layover period. His appetite was almost normal before recycling with class 12-91. Following graduation he tried to control his food intake after 1 week.

Ranger D reported overeating and the use of Tums or Rolaids during the Desert phase layover. He had diarrhea 6 times/day for 14 days which he attributed to a lactose intolerance and the consumption of milk products. Following graduation with class 12-91, he tried to control his food intake after 3-4 days.

Ranger E reported eating until he was sick. He took Tums for indigestion during the Desert phase layover period. He ate whenever he was hungry; after 2 weeks his intake started to decrease. He had diarrhea 4 times/day for 14 days in the Desert layover and to a lesser extent after graduating with class 12-91.

Ranger F reported that "his body said he was full, but his mind said to eat more - so he ate." He ate constantly for the first month after Ranger school; now he eats 3 meals/day with snacks, an increase in meal frequency but a decreased amount per meal, over his previous eating habits. He had diarrhea and cramping for 10-20 days during the Desert phase layover and again following graduation with class 12-91.

Ranger G reported that he ate constantly during the first week after Ranger school. He had diarrhea 4 times/day and cramping 2 times/day for 14 days.

Ranger H reported that initially he had a pronounced hunger and consequent overeating which gradually went back to normal. After 3 days he tried to exert some control over his eating habits. He experienced nausea once/day and diarrhea for 3 days.

Table 2. Individual changes in food consumption and food cravings.

Ranger #1 reported an increased consumption of beef, doughnuts/cookies/pastries salty foods, ice cream, and chocolate candy, candy or cakes. He had a strong craving for chocolate and a "desire" for sweet foods although he normally does not eat much sweet food. During his adjustment period, he was able to eat a whole cake at one sitting. His cravings lasted for 3 months.

Ranger #2 reported an increased consumption of beef, fried foods, breads, water, and peanut butter, with cravings of peanut butter, cocoa, and hamburgers. He ate less than usual amounts of ice cream and fruits or vegetables.

Ranger #3 reported eating more of all foods. He listed pizza and lasagna as cravings, but stated "I can't really narrow it down - I wanted everything the same." After a 1-1/2 months he said that he tried to eat a more healthful diet.

Ranger #4 reported eating more of all foods. He reported craving "chow hall" food, especially breakfast foods, and he stated that he wasn't being served as much as he wanted.

Ranger #5 reported an increased consumption of doughnuts/cookies/cakes/pastries, ice cream, milk, and pizza. He said he ate more of these foods since he was deprived of them during Ranger school.

Ranger #6 reported an increased consumption of beef, fried foods, doughnuts/cookies/cakes/pastries, salty snacks, and beer. He reported craving Taco Bell tacos, peanut butter, real blueberry pancakes, and biscuits & gravy.

Ranger #7 reported an increased consumption of doughnuts/cookies/cakes/pastries, salty snacks, and ice cream. He reported craving peanut butter, pasta, and pizza. He ate anything he craved.

Ranger #8 reported an increased consumption of doughnuts/cookies/cakes/pastries, salty snacks, ice cream, chocolate candy, and beverages (orange juice, soda). Foods reported as cravings were ice cream, all kinds of candy, chocolate, pizza, and chips. The cravings lasted for 3-4 months.

Weight regain. All of the soldiers regained lost weight rapidly after Ranger training; 5/8 gained weight to 10 pounds or more over their normal weight; several of these soldiers wanted to lose 5-10 pounds now, but one wanted to gain (see Table 3). In general, the recollections of weight loss were greater than the actual measured changes but the initial weights were also remembered to be higher, suggesting that some of the soldiers may have lost weight during the Ranger Indoctrination Program (RIP), in their training in the Fort Benning "gulag," or in the one week "zero week" acclimation course just prior to the start of Ranger training and the time when the initial measurements were made. Conceivably, the true weight loss for these soldiers was even greater than the 15.6% average measured across Ranger training.

Sleep quality & duration. Two Rangers stated that they had interrupted sleep, sleeping lightly and waking frequently for the first month after Ranger school. Four others stated that their sleep increased by at least 2 hours/night over pre-Ranger usual sleep patterns for 10 days to several months after training. The remaining 2 Rangers reported no problems with sleep and no change over previous patterns.

Physical capacity. Three Rangers reported that their scores on the first APFT (Army Physical Fitness Test) after their return from Ranger training were as good as when they started Ranger school (scores: 285, 287, 298). The APFT performance of the others was worse. They described their physical condition as "generally weaker" and offered descriptors such as "easily winded and tired," "always fatigued," and feeling "broken down." Three attributed their difficulty to lack of exercise training "due to laziness" (laziness was not precisely distinguished from "fatigue" or "loss of motivation"). For most of the soldiers, this period of poor exercise discipline lasted for 2-4 weeks and then old training habits were restored. The time to return to peak condition was not well defined.

Leave/recovery time. Several of the Rangers wanted to take leave time when they first returned from Ranger school but were immediately returned to duty; 4 had planned for leave before Ranger training began but 2 of these were disapproved because of a unit block leave policy and because of a scheduled 130 day unit mission; one who did take a 15 day leave wanted more time but had to return to attend PLDC. Three others wanted leave for recovery time when they returned but were denied it; instead 2 of these ended up with 10-12 day convalescent leaves and 1 was awarded a 4-day pass. The eighth Ranger did not ask for leave.

Table 3. Individual recollections about weight loss and regain. Weights and weight loss recorded in the study are given in brackets.

Graduating with class 11-91:

I. Start: 145 [149] lbs; usual: 145 lbs; lost: 20 [20.3] lbs. Gained all the weight plus 10 lbs in 14 days after Ranger school. Wanted to keep weight at 160 (i.e. lose only 5 lbs) but now down to 155 lbs [155 lbs].

II. Start: 170 [165] lbs; usual: 175 lbs; lost: 42 [25.2] lbs. Gained 42 lbs lost in 30 days. Went up to 10 lbs over weight entered but only 5 lbs over usual weight [Now: 172.7 lbs].

Recycling desert phase in class 12-91:

III. Start: 150 [178] lbs; usual: 155 lbs; lost: 38 [58.8] lbs. Gained all the weight back by the end of Desert phase layover but lost it again at end of 12-91 Desert phase training. Gained the 38 lbs lost again in 30 days [Now: 153.0 lbs].

IV. Start: 198 [195] lbs; usual: 198 lbs; lost: 40 [28.8] lbs. Gained 40 lbs lost in 21 days to "normal weight" [Now: 203.5 lbs].

V. Start: 160 [153] lbs; usual: 155 lbs; lost: 30-35 [25.2] lbs. Gained 50 lbs at the end of 3-1/2 week Desert phase layover. At graduation, still had approximately 10 lbs to lose to return to normal weight [Now: 155.8 lbs].

VI. Start: 230 [211] lbs; usual: 215 lbs; lost: 60 [43.8] lbs. Gained all 60 lbs in 60 days [Now: 214.5 lbs].

VII. Start: 165 [153] lbs; usual: 165 lbs; lost 42 [14.0] lbs. Gained 35 lbs in 9 days and then continued to gain. Now weighs 175 lbs [167.5 lbs] and wants to lose 10 lbs.

VIII. Start: 155 [139] lbs; usual: 145 lbs; lost: 25-30 [15.5 lbs]. Gained 47 lbs by the end of 3-1/2 week Desert phase layover. By graduation, 15 lbs over usual weight [Now: 145.2 lbs].

Perceived and measured weights are given as: "start"= beginning of the course; "lost"= weight lost in 8-1/2 weeks of class 11-91.

CONCLUSIONS

The findings here are quite similar to those noted in the Minnesota Study, where calorie deprived volunteers became obsessed with food and this carried into the refeeding stage (1). The recollections of these 8 soldiers were consistent with other anecdotal evidence obtained at the end of the course, where students had packets of index cards with listings of favorite resturants and recipes which they had constructed during the course. At least 2 soldiers in good academic standing had been removed from the class in the last phase for food violations: one had walked out of a dining facility with an orange and the other had ordered pizza while hospitalized for 24 hours.

Contrary to some expectations, there were no apparent residual problems 6 months after the end of Ranger training. The soldiers had all returned to normal body weights and body composition and there were no apparent medical problems (except for one set of numb toes). The impression of the examining physician was that these 8 soldiers were characterized by superb health and fitness.

The problems which these Rangers reported retrospectively occurred primarily within the first 2 months after Ranger training, with overeating, diarrhea (probably related to the overeating), sleep disturbances, and reduced physical capacity.

These results indicate that a more detailed study of the post-Ranger training recovery should focus on the first 2 months, should include body composition, physical performance, and sleep activity, as well as detailed analysis of eating habits.

ACKNOWLEDGEMENTS

We are indebted to the 8 soldiers who participated in this followup study for their patience and cooperation.

REFERENCE

1. Schiele BC, Brozek J. "Experimental neurosis" resulting from semistarvation in man. Psychosomatic Medicine 1948;10:31-50.